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| (54) Title: METHOD FOR PREPARING POLYPEPTIDE VARIANTS   |  |  |  |
| (57) Abstract   |  |  |  |
| <p>The present invention relates to a method for preparing positive polypeptide variants by shuffling different nucleotide sequences of homologous DNA sequences by <i>in vivo</i> recombination comprising the steps of a) forming at least one circular plasmid comprising a DNA sequence encoding a polypeptide, b) opening said circular plasmid(s) within the DNA sequence(s) encoding the polypeptide(s), c) preparing at least one DNA fragment comprising a DNA sequence homologous to at least a part of the polypeptide coding region on at least one of the circular plasmid(s), d) introducing at least one of said opened plasmid(s), together with at least one of said homologous DNA fragment(s) covering full-length DNA sequences encoding said polypeptide(s) or parts thereof, into a recombination host cell, e) cultivating said recombination host cell, and f) screening for positive polypeptide variants.</p> |  |  |  |

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Title: Method for preparing polypeptide variants

#### FIELD OF THE INVENTION

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The present invention relates to a method for preparing polypeptide variants by *in vivo* recombination.

#### 10 BACKGROUND OF THE INVENTION

The advantages of producing biologically active polypeptides by cloning naturally occurring DNA sequences from microorganisms, such as fungal organisms and bacteria using recombinant DNA technology  
15 have been known for quite some years.

Preparation of novel polypeptide variants and mutants, such as novel modified enzymes with altered characteristics, e.g. specific activity, substrate specificity, pH-optimum, pI,  $K_m$ ,  $V_{max}$  etc., have  
20 especially during the recent years diligently and successfully been used for obtaining polypeptides with improved properties.

For instance, within the technical field of enzymes the washing and/or dishwashing performance of e.g. proteases, lipases, amylases  
25 and cellulases have been improved significantly.

In most cases these improvements have been obtained by site-directed mutagenesis resulting in substitution, deletion or insertion of specific amino acid residues which have been chosen either on the  
30 basis of their type or on the basis of their location in the secondary or tertiary structure of the mature enzyme (see for instance US patent no. 4,518,584).

An alternative general approach for modifying proteins and enzymes have been based on random mutagenesis, for instance, as disclosed in  
35 US 4,894,331 and WO 93/01285

As it is a cumbersome and time consuming process to obtain polypeptide variants or mutants with improved functional properties a few alternative methods for rapid preparation of modified  
40 polypeptides have been suggested.

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Weber et al., (1983), Nucleic Acids Research, vol 11, 5661-5661, describes a method for modifying genes by *in vivo* recombination between to homologous genes. A linear DNA sequence comprising a plasmid vector flanked to a DNA sequence encoding alpha-1 human interferon in the 5'-end and a DNA sequence encoding alpha-2 human interferon in the 3'-end is constructed and transfected into a rec A positive strain of *E. coli*. Recombinants were identified and isolated using a resistance marker.

Pompon el al., (1989), Gene 83, p. 15-24, describes a method for shuffling gene domains of mammalian cytochrome P-450 by *in vivo* recombination of partially homologous sequences in *Saccharomyces cerevisiae* by transforming *Saccharomyces cerevisia* with a linearized plasmid with filled-in ends, and a DNA fragment being partially homologous to the ends of said plasmid.

Stemmer, (1994), Proc. Natl. Acad. Sci. USA, Vol. 91, 10747-10751; Stemmer, (1994), Nature, vol. 370, 389- 391, concern methods for shuffling homologous DNA sequences by an *in vitro* PCR method. One cycle of shuffling consists of digesting a pool of homologous genes with DNase I. The resulting small fragments are reassembled into full-length genes. Positive recombinant genes containing shuffled DNA sequences are selected from a DNA library based on their improved function. Positive recombinants can be used as the starting material for (an)other shuffling round(s).

US patent no. 5,093,257 (Assignee: Genencor Int. Inc.) discloses a method for producing hybrid polypeptides by *in vivo* recombination. Hybrid DNA sequences are produced by forming a circular vector comprising a replication sequence, a first DNA sequence encoding the amino-terminal portion of the hybrid polypeptide, a second DNA sequence encoding the carboxy-terminal portion of said hybrid polypeptide. The circular vector is transformed into a rec positive microorganism in which the circular vector is amplified. This results in recombination of said circular vector mediated by the naturally occurring recombination mechanism of the rec positive microorganism, which include prokaryotes such as *Bacillus* and *E. coli*, and leukaryotes such as *Saccharomyces cerevisiae*.

Despite the existence of the above methods there are still need for even better iterative *in vivo* recombination methods for preparing novel positive polypeptide variants.

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#### SUMMARY OF THE INVENTION

The object of the present invention is to provide an improved method for preparing positive polypeptide variants by an *in vivo* recombination method.

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The inventor of the present invention have surprisingly found that such positive polypeptide variants may advantageously be prepared by shuffling different nucleotide sequences of homologous DNA sequences by *in vivo* recombination comprising the steps of

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- a) forming at least one circular plasmid comprising a DNA sequence encoding a polypeptide,
- b) opening said circular plasmid(s) within the DNA sequence(s) encoding the polypeptide(s),
- c) preparing at least one DNA fragment comprising a DNA sequence homologous to at least a part of the polypeptide coding region on at least one of the circular plasmid(s), d) introducing at least one of said opened plasmid(s), together with at least one of said homologous DNA fragment(s) covering full-length DNA sequences encoding said polypeptide(s) or parts thereof, into a recombination host cell,
- e) cultivating said recombination host cell, and
- f) screening for positive polypeptide variants.

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#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows the yeast expression plasmid pJSO26 comprising DNA sequence encoding the *Humicola lanuginosa* lipase gene.

Figure 2 shows the yeast expression plasmid pJSO37, comprising DNA sequence encoding the *Humicola lanuginosa* lipase gene containing twelve additional restriction sites.

Figure 3 shows the plasmid pJSO26.

Figure 4 shows the plasmid pJSO37.

Figure 5 shows the *in vivo* recombination of the 0.9 kb synthetic wild-type *Humicola lanuginosa* lipase with pJSO37 using *Saccharomyces*

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*cerevisiae* as the recombination host cell (described in Example 1). Figure 6 shows the *in vivo* recombination of a DNA fragment prepared from *Humicola lanuginosa* lipase variant (y) with *Humicola lanuginosa* lipase variant (d) comprised in a plasmid using *Saccharomyces cerevisiae* as the recombination host cell (described in Example 2). Figure 7 shows an overview over the location of the inactivation site of the *Humicola lanuginosa* lipase gene and the number of the clone (referred to as "blue number" in the tables). Location of restriction enzyme sites and clone numbers are relative to the initiation codon of the lipase gene. In all cases a stop codon was located in the new reading frame 10 to 50 bp from the frameshift. Figure 8 shows an overview of the creation of active *humicola lanuginosa* lipase genes from the recombinations in table 2A and B by a "mosaic mechanism". Lines indicate the introduction of the fragment sequence into the vector and lines with a x indicate sequences that are not introduced in the active lipase colonies. The primers used for the PCR fragment are shown together with the location of the frameshift mutation (marked by the restriction site used for the construction). Figure 9 shows an overview of fragments used in the recombination of 2 partial overlapping fragments into a gapped vector. The primers used for the PCR fragments are shown together with the location of the frameshift mutation (if not wild type). Figure 10 shows an overview of fragments used in the recombination of 3 partial overlapping fragments into a gapped vector. The primers used for the PCR fragments are shown. The overlap between PCR353 and 355 is only a 10 bp.

#### DETAILED DESCRIPTION OF THE INVENTION

The object of the present invention is to provide an improved method for preparing positive polypeptide variants by an iterative *in vivo* recombination method.

The inventor of the present invention have surprisingly found an efficient method for shuffling homologous DNA sequences in an *in vivo* recombination system using a eukaryotic cell as a recombination host cell.

A "recombination host cell" is in the context of the present invention a cell capable of mediating shuffling of a number of homologous DNA sequences.

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The term "shuffling" means recombination of nucleotide sequence(s) between two or more homologous DNA sequences resulting in output DNA sequences (i.e. DNA sequences having been subjected to a shuffling cycle) having a number of nucleotides exchanged, in comparison to the input DNA sequences (i.e. starting point homologous DNA sequences).

An important advantage of the invention is that mosaic DNA sequences with multiple replacement points or replacements, not related to the opening site, is created, which is not discovered in Pompon's method.

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An other important advantage of the present invention is that when using a mixture of fragments and opened vectors (in the screening set up) it gives the possibility of many different clones to recombine pairwise or even triplewise (as can be seen in a couple of examples below).

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The *in vivo* recombination method of the invention simple to perform and results in a high level of mixing of homologous genes or variants. A large number of variants or homologous genes can be mixed in one transformation. The mixing of improved variants or wild type genes followed by screening increases the number of further improved variants manyfold compared to doing only random mutagenesis.

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Recombination of multiple overlapping fragments is possible with a high efficiency increasing the mixing of variants or homologous genes using the *in vivo* recombination method. An overlap as small as 10 bp is sufficient for recombination which may be utilized for very easy domain shuffling of even distantly related genes.

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The invention relates to a method for preparing polypeptide variants by shuffling different nucleotide sequences of homologous DNA sequences by *in vivo* recombination comprising the steps of

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- a) forming at least one circular plasmid comprising a DNA sequence encoding a polypeptide,  
b) opening said circular plasmid(s) within the DNA sequence(s) encoding the polypeptide(s),  
5 c) preparing at least one DNA fragment comprising a DNA sequence homologous to at least a part of the polypeptide coding region on at least one of the circular plasmid(s), d) introducing at least one of said opened plasmid(s), together with at least one of said homologous DNA fragment(s) covering full-length DNA sequences  
10 encoding said polypeptide(s) or parts thereof, into a recombination host cell,  
e) cultivating said recombination host cell, and  
f) screening for positive polypeptide variants.

- 15 According to the invention more than one cycle of step a) to f) may be performed.

The opening of the plasmid(s) in step b) can be directed toward any site within the polypeptide coding region of the plasmid. The  
20 plasmid(s) may be opened by any suitable methods known in the art. The opened ends of the plasmid may be filled-in with nucleotides as described in Pompon et al. (1989), supra. It is preferred not to fill in the opened ends as it might create a frameshift.

- 25 It is preferred to open the plasmid(s) around the middle of the polypeptide coding DNA sequence(s), as this is believed to result in a more effective recombination between DNA fragment(s) and opened plasmid(s).

- 30 In an embodiment of the invention the DNA fragment(s) is(are) prepared under conditions resulting in a low, medium or high random mutagenesis frequency.

- To obtain low mutagenesis frequency the DNA sequence(s) (comprising  
35 the DNA fragment(s)) may be prepared by a standard PCR amplification method (US 4,683,202 or Saiki et al., (1988), Science 239, 487 - 491).

- A medium or high mutagenesis frequency may be obtained by performing  
40 the PCR amplification under conditions which increase the mis-incorporation of nucleotides, for instance as described by Deshler,



(1992), GATA 9(4), 103-106; Leung et al., (1989), Technique, Vol. 1, No. 1, 11-15.

5 It is also contemplated according to the invention to combine the PCR amplification (i.e. according to this embodiment also DNA fragment mutation) with a mutagenesis step using a suitable physical or chemical mutagenizing agent, e.g., one which induces transitions, transversions, inversions, scrambling, deletions, and/or insertions.

10 In the context of the present invention the term "positive polypeptide variants" means resulting polypeptide variants possessing functional properties which has been improved in comparison to the polypeptides producible from the corresponding input DNA sequences. Examples, of such improved properties can be as different as e.g.  
15 biological activity, enzyme washing performance, antibiotic resistance etc.

Consequently, which screening method to be used for identifying positive variants depend on the desired improved property of the  
20 polypeptide variant in question.

If, for instance, the polypeptide in question is an enzyme and the desired improved functional property is the wash performance, the screening in step f) may conveniently be performed by use of a  
25 filter assay based on the following principle:

The recombination host cell is incubated on a suitable medium and under suitable conditions for the enzyme to be secreted, the medium being provided with a double filter comprising a first protein-binding filter and on top of that a second filter exhibiting a low  
30 protein binding capability. The recombination host cell is located on the second filter. Subsequent to the incubation, the first filter comprising the enzyme secreted from the recombination host cell is separated from the second filter comprising said cells. The first  
35 filter is subjected to screening for the desired enzymatic activity and the corresponding microbial colonies present on the second filter are identified.

The filter used for binding the enzymatic activity may be any  
40 protein binding filter e.g. nylon or nitrocellulose. The topfilter carrying the colonies of the expression organism may be any filter

that has no or low affinity for binding proteins e.g. cellulose acetate or Durapore<sup>®</sup>. The filter may be pre-treated with any of the conditions to be used for screening or may be treated during the detection of enzymatic activity.

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The enzymatic activity may be detected by a dye, fluorescence, precipitation, pH indicator, IR-absorbance or any other known technique for detection of enzymatic activity.

10 The detecting compound may be immobilized by any immobilizing agent e.g. agarose, agar, gelatine, polyacrylamide, starch, filter paper, cloth; or any combination of immobilizing agents.

15 If the improved functional property of the polypeptide is not sufficiently good after one cycle of shuffling, the polypeptide may be subjected to another cycle.

In an embodiment of the invention at least one shuffling cycle is a backcrossing cycle with the initially used DNA fragment, which may  
20 be the wild-type DNA fragment. This eliminates non-essential mutations. Non-essential mutations may also be eliminated by using wild-type DNA fragments as the initially used input DNA material.

25 It is to be understood that the method of the invention is suitable for all types of polypeptide, including enzymes such as proteases, amylases, lipases, cutinases, amylases, cellulases, peroxidases and oxidases.

Also contemplated according to the invention is polypeptides having  
30 biological activity such as insulin, ACTH, glucagon, somatostatin, somatotropin, thymosin, parathyroid hormone, pigmentary hormones, somatomedin, erythropoietin, luteinizing hormone, chorionic gonadotropin, hypothalamic releasing factors, antidiuretic hormones, thyroid stimulating hormone, relaxin, interferon, thrombopoietin  
35 (TPO) and prolactin.

Especially contemplated according to the present invention is initially to use input DNA sequences being either wild-type, variant or modified DNA sequences, such as a DNA sequences coding for wild-type, variant or modified enzymes, respectively, in particular  
40 enzymes exhibiting lipolytic activity.

In an embodiment of the invention the lipolytic activity is a lipase activity derived from the filamentous fungi of the *Humicola* sp., in particular *Humicola lanuginosa*, especially *Humicola lanuginosa*.

5 In a specific embodiment of the invention the initially used input DNA fragment to be shuffled with a homologous polypeptide is the wild-type DNA sequence encoding the *Humicola lanuginosa* lipase derived from *Humicola lanuginosa* DSM 4109 described in EP 305 216  
10 (Novo Nordisk A/S).

Also specifically encompassed by the scope of the invention is input DNA sequences selected from the group of vectors (a) to (f) and/or DNA fragments (g) to (aa) coding for *Humicola lanuginosa* lipase  
15 variants from the list below in the Material and Method section.

Throughout the present application the name *Humicola lanuginosa* has been used to identify one preferred parent enzyme, i.e. the one mentioned immediately above. However, in recent years *H. lanuginosa*  
20 has also been termed *Thermomyces lanuginosus* (a species introduced the first time by Tsiklinsky in 1989) since the fungus show morphological and physiological similarity to *Thermomyces lanuginosus*. Accordingly, it will be understood that whenever reference is made to *H. lanuginosa* this term could be replaced by  
25 *Thermomyces lanuginosus*. The DNA encoding part of the 18S ribosomal gene from *Thermomyces lanuginosus* (or *H. lanuginosa*) have been sequenced. The resulting 18S sequence was compared to other 18S sequences in the GenBank database and a phylogenetic analysis using parsimony (PAUP, Version 3.1.1, Smithsonian Institution, 1993) have  
30 also been made. This clearly assigns *Thermomyces lanuginosus* to the class of *Plectomycetes*, probably to the order of *Eurotiales*. According to the Entrez Browser at the NCBI (National Center for Biotechnology Information), this relates *Thermomyces lanuginosus* to families like *Eremascaceae*, *Monoascaceae*, *Pseudoeurotiaceae* and  
35 *Trichocomaceae*, the latter containing genera like *Emericella*, *Aspergillus*, *Penicillium*, *Eupenicillium*, *Paecilomyces*, *Talaromyces*, *Thermoascus* and *Sclerocleista*.

Consequently, such genes encoding lipolytic enzymes of filamentous  
40 fungi of the genera *Emericella*, *Aspergillus*, *Penicillium*,

*Eupenicillium*, *Paecilomyces*, *Talaromyces*, *Thermoascus* and *Sclerocleista* are also specifically contemplated according to the present invention.

- 5 Other examples of relevant filamentous fungi genes encoding lipolytic enzymes include strains of the *Absidia* sp. e.g. the strains listed in WO 96/13578 (from Novo Nordisk A/S) which are hereby incorporated by reference. *Absidia* sp. strains listed in WO 96/13578 include *Absidia blakesleeana*, *Absidia corymbifera* and  
10 *Absidia reflexa*.

Strains of *Rhizopus* sp., in particular *Rh. niveus* and *Rh. oryzae* are also contemplated according to the invention.

- 15 The lipolytic gene may also be derived from a bacteria, such as a strain of the *Pseudomonas* sp., in particular *Ps. fragi*, *Ps. stutzeri*, *Ps. cepacia* and *Ps. fluorescens* (WO 89/04361), or *Ps. plantarii* or *Ps. gladioli* (US 4,950,417) or *Ps. alcaligenes* and *Ps. pseudoalcaligenes* (EP 218 272, EP 331 376, or WO 94/25578  
20 (disclosing variants of the *Ps. pseudoalcaligenes* lipolytic enzyme), the *Pseudomonas* sp. variants disclosed in EP 407 225, or a *Pseudomonas* sp. lipolytic enzyme, such as the *Ps. mendocina* (also termed *Ps. putida*) lipolytic enzyme described in WO 88/09367 and US 5,389,536 or variants thereof as described in US 5,352,594, or *Ps.*  
25 *aeruginosa* or *Ps. glumae*, or *Ps. syringae*, or *Ps. wisconsinensis* (WO 96/12012 from Solvay) or a strain of *Bacillus* sp., e.g. the *B. subtilis* described by Dartois et al., (1993) *Biochimica et Biophysica acta* 1131, 253-260, or *B. stearothermophilus* (JP 64/7744992) or *B. pumilus* (WO 91/16422) or a strain of *Streptomyces*  
30 sp., e.g. *S. scabies*, or a strain of *Chromobacterium* sp. e.g. *C. viscosum*.

- In connection with the *Pseudomonas* sp. lipases it has been found that lipases from the following organisms have a high degree of  
35 homology, such as at least 60% homology, at least 80% homology or at least 90% homology, and thus are contemplated to belong to the same family of lipases: *Ps. ATCC21808*, *Pseudomonas* sp. lipase commercially available as Liposam®, *Ps. aeruginosa* EF2, *Ps. aeruginosa* PAC1R, *Ps. aeruginosa* PA01, *Ps. aeruginosa* TE 3285, *Ps.*  
40 sp. 109, *Ps. pseudoalcaligenes* M1, *Ps. glumae*, *Ps. cepacia* DSM 3959,

*Ps. cepacia* M-12-33, *Ps. sp.* KWI-56, *Ps. putida* IFO 3458, *Ps. putida* IFO 12049 (Gilbert, E. J., (1993), *Pseudomonas* lipases: Biochemical properties and molecular cloning. *Enzyme Microb. Technol.*, 15, 634-645). The species *Pseudomonas cepacia* has recently been reclassified as *Burkholderia cepacia*, but is termed *Ps. cepacia* in the present application.

Also genes encoding lipolytic enzymes from yeasts are relevant, and include lipolytic genes from *Candida* sp., in particular *Candida rugosa*, or *Geotrichum* sp., in particular *Geotrichum candidum*.

Specific examples of microorganisms comprising genes encoding lipolytic enzymes used for commercially available products and which may serve as donor of genes to be shuffled according to the invention include *Humicola lanuginosa*, used in Lipolase®, Lipolase® Ultra, *Ps. mendocina* used in Lumafast®, *Ps. alcaligenes* used in Lipomax®, *Fusarium solani*, *Bacillus* sp. (US 5427936, EP 528828), *Ps. mendocina*, used in Liposam®.

Also the *Pseudomonas* sp. lipase gene shown in SEQ ID NO 14 are specifically contemplated according to the invention.

It is to be emphasized that genes encoding lipolytic enzyme to be shuffled according to the invention may be any of the above mentioned genes of lipolytic enzymes and any variant, modification, or truncation thereof. Examples of such genes which are specifically contemplated include the genes encoding the enzymes described in WO 92/05249, WO 94/01541, WO 94/14951, WO 94/25577, WO 95/22615 and a protein engineered lipase variants as described in EP 407 225; a protein engineered *Ps. mendocina* lipase as described in US 5,352,594; a cutinase variant as described in WO 94/14964; a variant of an *Aspergillus* lipolytic enzyme as described in EP patent 167,309; and *Pseudomonas* sp. lipase described in WO 95/06720.

A request to the DNA sequences, encoding the polypeptide(s), to be shuffled, is that they are at least 60%, preferably at least 70%, better more than 80%, especially more than 90%, and even better up to almost 100% homologous. DNA sequences being less homologous will have less inclination to interact and recombine.

It is also contemplated according to the invention to shuffle parent (homologous) wild type organisms of different genera.

Further, the DNA fragment(s) to be shuffled may preferably have a length of from about 20 bp to 8 kb, preferably about 40 bp to 6 kb, more preferred about 80 bp to 4 kb, especially about 100 bp to 2 kb, to be able to interact optimally with the opened plasmid.

The method of the invention is very efficient for preparing polypeptide variants in comparison to prior art method comprising transforming linear DNA fragments/sequences.

The inventor found that the transformation frequency of a mixture of opened plasmid and a DNA fragment were significantly higher than when transforming a plasmid cut at the same site alone. The transformation frequency of the opened plasmid and DNA fragment were as high as for uncut plasmid.

Without being limited to any theory it is believed that the opening of the plasmid(s) restrict(s) the replication of (opened) plasmid(s) when not interacting with at least one DNA fragment. In accordance with this an increased number of recombined DNA sequences were found after only one shuffling cycle.

As described in Example 1 50% of the resulting transformants contained recombined DNA sequences of both input DNA sequences. As high as 20% of the total number of recombined DNA sequences were "random" mixtures (i.e. having more than one region of nucleotides exchanged).

The input DNA sequences may be any DNA sequences including wild-type DNA sequences, DNA sequences encoding variants or mutants, or modifications thereof, such as extended or elongated DNA sequences, and may also be the outcome of DNA sequences having been subjected to one or more cycles of shuffling (i.e. output DNA sequences) according to the method of the invention or any other method (e.g. any of the methods described in the prior art section).

When using the method of the invention the output DNA sequences (i.e. shuffled DNA sequences), have had a number of nucleotide(s) exchanged. This results in replacement of at least one amino acid within the polypeptide variant, if comparing it with the parent polypeptide. It is to be understood that also silent mutations is

contemplated (i.e. nucleotide exchange which does not result in changes in the amino acid sequence).

5 However, the method of the present invention will in most cases lead to the replacement of a considerable number of amino acid and may in certain cases even alter the structure of one or more polypeptide domains (i.e. a folded unit of polypeptide structure).

10 According to the present invention more than two DNA sequences are shuffled at the same time. Actually any number of different DNA fragments and homologous polypeptides comprised in suitable plasmids may be shuffled at the same time. This is advantageous as a vast number of quite different variants can be made rapidly without an abundance of iterative procedures.

15 The inventor have tested the nucleotide shuffling method of the invention using significantly more than two homologous DNA sequences. As described in Example 2 it was surprisingly found that the method of the invention advantageously can be used for  
20 recombining more than two DNA sequences.

One cycle of shuffling according to the method of the invention may result in the exchange of from 1 to 1000 nucleotides into the opened plasmid DNA sequence encoding the polypeptide in question. The  
25 exchanged nucleotide sequence(s) may be continuous or may be present as a number of sub-sequences within the full-length sequence(s).

To support the present invention the inventor made a number of additional experiments on different aspect on the method of the  
30 invention. The experiments are described below and illustrated in the Example 3 to 6 below.

A number of vectors and fragments comprising an inactivated synthetic *Humicola lanuginosa* lipase genes were constructed by  
35 introducing frameshift/stop codon mutations in the lipase gene at various positions. These were used for monitoring the *in vivo* recombination of different combinations of opened vector(s) and DNA fragments. The number of active lipase colonies were scored as described in Example 3. The number of colonies determines the  
40 efficiency of the opened vector(s) and fragment(s) recombination.

One frameshift mutation in said *Humicola lanuginosa* lipase gene in the opened vector and another in the fragment on the opposite side of the opening site gave 3 to 32% of active lipase colonies depending on the location and combination. It was concluded that the closer that the mutation is at the ends of the vector the higher mixing.

One frameshift mutation in the opened vector and two in the fragment on each side of the opening site gave 4 to 42% of active colonies depending on the location and combination. Some of these active colonies can be considered to be mosaics, not only related to the opening site.

Two frameshift mutations in the opened vector on each side of the opening site and one in the fragment gave 0.5 to 3.1% of active colonies depending on the location and combination. Most of these active colonies are mosaics of the "parent" DNA.

Two frameshift mutations in the opened vector on each side of the opening site and a wild type fragment gave 7.7 to 10.7% of active colonies depending on the location.

It was also found that the amount of vectors relative to fragments and the size of the fragments are also influencing the result.

Using of the *S. cerevisiae* rad52 mutants as the recombination host cell showed that the rad52 mutant transformed very well with wild type plasmid(s) and expressed the *Humicola lanuginosa* lipase gene, but gave no transformants at all with the opened vectors and fragments.

The RAD52 function is required for "classical recombination" (but not for unequal sister-strand mitotic recombination) showing that the recombination of opened vector and fragment could involve a classical recombination mechanism.

Classical recombination is the recombination mechanism involved in the recombination between genes located on nonsister chromatids of homologous chromosomes as defined in for example Petes TD, Malone RE and Symington LS (1991) "Recombination in Yeast", page 407-522, in The Molecular and Cellular Biology of the Yeast *Saccharomyces*,



Volume 1 (eds. Broach JR, Pringle JR and Jones EW), Cold Spring Harbor Laboratory Press, New York.

Multiple partially overlapping fragments

- 5 The inventor also tested recombination of multiple partial overlapping fragments using the method of the invention.

10 The recombination of 2 and 3 partial overlapping fragments into a gapped (i.e. that the opening result in cutting out of a little part of the gene) vector were tested and gave a high recovery of recombined *Humicola lanuginosa* lipase gene. The recovery of active lipase gene from different combinations of inactivated *Humicola lanuginosa* genes was tested for the recombination of 2 partial overlapping fragments. The tendency was a higher mixing in the  
15 overlapping region between the 2 fragments in the gapped region than in the vector and fragment overlap.

When recombining many fragments from the same region, the multiple overlapping fragment technique will increase the mixing by itself,  
20 but it is also important to have a relative high random mixing in overlapping regions in order to mix closely located variants/differences.

25 An overlap as small as 10 bp between two fragments were found to be sufficient to obtain a very efficient recombination. Therefore, overlapping in the range from 5 to 5000 bp, preferably from 10 bp to 500 bp, especially 10 bp to 100 bp is suitable according to the method of the invention.

30 According to this embodiment of the present invention 2 or more overlapping fragments, preferable 2 to 6 overlapping fragments, especially 2 to 4 overlapping fragments may advantageously be used as input fragments in a shuffling cycle.

35 Besides increasing the mixing of genes, this is a very useful method for domain shuffling by creating small overlaps between DNA fragments from different domains and screen for the best combination.

40 For instance, in the case of three DNA fragments the overlapping regions may be as follows:

- the first end of the first fragment overlaps the first end of the opened plasmid,
- the first end of the second fragment overlaps the second end of the first fragment, and the second end of the second fragment overlaps the first end of the third fragment,
- the first end of the third fragment overlaps (as stated above) the second end of the second fragment, and the second end of the third fragment overlaps the second end of the opened plasmid.

It is to be understood that when using two or more DNA fragments as starting material it is preferred to have continuous overlaps between the ends of the plasmid and the DNA fragments.

Even though it is preferred to shuffle homologous DNA sequences in the form of DNA fragment(s) and opened plasmid(s), it is also contemplated according to the invention to shuffle two or more opened plasmids comprising homologous DNA sequences encoding polypeptides. However, in such case it is compulsory to open the plasmids at different sites.

In an further embodiment of the invention two or more opened plasmids and one or more homologous DNA fragments are used as the starting material to be shuffled. The ratio between the opened plasmid(s) and homologous DNA fragment(s) preferably lie in the range from 20:1 to 1:50, preferable from 2:1 to 1:10 (mol vector:mol fragments) with the specific concentrations being from 1 pM to 10 M of the DNA.

The opened plasmids may advantageously be gapped in such a way that the overlap between the fragments is deleted in the vector in order to select for the recombination).

Preparing the DNA fragment

The DNA fragment to be shuffled with the homologous polypeptide comprised in an opened plasmid may be prepared by any suitable method. For instance, the DNA fragment may be prepared by PCR amplification (polymerase chain reaction), as described above, of a plasmid or vector comprising the gene of the polypeptide, using specific primers, for instance as described in US 4,683,202 or Saiki et al., (1988), Science 239, 487 - 491. The DNA fragment may also be cut out from a vector or plasmid comprising the desired DNA sequence by digestion with restriction enzymes, followed by isolation using e.g. electrophoresis.

The DNA fragment encoding the homologous polypeptide in question may alternatively be prepared synthetically by established standard methods, e.g. the phosphoramidite method described by Beaucage and Caruthers, (1981), Tetrahedron Letters 22, 1859 - 1869, or the method described by Matthes et al., (1984), EMBO Journal 3, 801 - 805. According to the phosphoramidite method, oligonucleotides are synthesized, e.g. in an automatic DNA synthesizer, purified, annealed, ligated and cloned in suitable vectors.

Furthermore, the DNA fragment may be of mixed synthetic and genomic, mixed synthetic and cDNA or mixed genomic and cDNA origin prepared by ligating fragments of synthetic, genomic or cDNA origin (as appropriate), the fragments corresponding to various parts of the entire DNA sequence, in accordance with standard techniques.

The plasmid

The plasmid comprising the DNA sequence encoding the polypeptide in question may be prepared by ligating said DNA sequence into a suitable vector or plasmid, or by any other suitable method.

Said vector may be any vector which may conveniently be subjected to recombinant DNA procedures. The choice of vector will often depend on the recombination host cell into which it is to be introduced.

Thus, the vector may be an autonomously replicating vector, i.e. a vector which exists as an extrachromosomal entity, the replication of which is independent of chromosomal replication, e.g. a plasmid. Alternatively, the vector may be one which, when introduced into the recombination host cell, is integrated into the host cell genome and

replicated together with the chromosome(s) into which it has been integrated.

5 To facilitate the screening process it is preferred that the vector is an expression vector in which the DNA sequence encoding the polypeptide in question is operably linked to additional segments required for transcription of the DNA. In general, the expression vector is derived from a plasmid, a cosmid or a bacteriophage, or may contain elements of any or all of these.

10 The term, "operably linked" indicates that the segments are arranged so that they function in concert for their intended purposes, e.g. transcription initiates in a promoter and proceeds through the DNA sequence coding for the polypeptide in question.

15 The promoter may be any DNA sequence which shows transcriptional activity in the recombination host cell of choice and may be derived from genes encoding proteins, such as enzymes, either homologous or heterologous to the host cell.

20 Examples of suitable promoters for use in yeast host cells include promoters from yeast glycolytic genes (Hitzeman et al., (1980), J. Biol. Chem. 255, 12073 - 12080; Alber and Kawasaki, (1982), J. Mol. Appl. Gen. 1, 419 - 434) or alcohol dehydrogenase genes (Young et al., in Genetic Engineering of Microorganisms for Chemicals (Hollaender et al, eds.), Plenum Press, New York, 1982), or the TPI1 (US 4,599,311) or ADH2-4c (Russell et al., (1983), Nature 304, 652 - 654) promoters.

30 Examples of suitable promoters for use in filamentous fungus host cells are, for instance, the ADH3 promoter (McKnight et al., (1985), The EMBO J. 4, 2093 - 2099) or the tpiA promoter. Examples of other useful promoters are those derived from the gene encoding *A. oryzae* TAKA amylase, *Rhizomucor miehei* aspartic proteinase, *A. niger* neutral  $\alpha$ -amylase, *A. niger* acid stable  $\alpha$ -amylase, *A. niger* or *A. awamori* glucoamylase (gluA), *Rhizomucor miehei* lipase, *A. oryzae* alkaline protease, *A. oryzae* triose phosphate isomerase or *A. nidulans* acetamidase. Preferred are the TAKA-amylase and gluA promoters.

40

The DNA sequence encoding polypeptide in question invention may also, if necessary, be operably connected to a suitable terminator, such as the human growth hormone terminator (Palmiter et al., op. cit.) or (for fungal hosts) the TPI1 (Alber and Kawasaki, op. cit.) or ADH3 (McKnight et al., op. cit.) terminators. The vector may further comprise elements such as polyadenylation signals (e.g. from SV40 or the adenovirus 5 Elb region), transcriptional enhancer sequences (e.g. the SV40 enhancer) and translational enhancer sequences (e.g. the ones encoding adenovirus VA RNAs).

The vector may further comprise a DNA sequence enabling the vector to replicate in the recombination host cell in question. When the host cell is a yeast cell, suitable sequences enabling the vector to replicate are the yeast plasmid 2 $\mu$  replication genes REP 1-3 and origin of replication.

The plasmid pY1 can be used for production of useful proteins and peptides, using filamentous fungi, such as *Aspergillus* sp., and yeasts as recombinant host cells (JP06245777-A).

The vector may also comprise a selectable marker, e.g. a gene the product of which complements a defect in the recombination host cell, such as the gene coding for dihydrofolate reductase (DHFR) or the *Schizosaccharomyces pombe* TPI gene (described by P.R. Russell, (1985), Gene 40, 125-130).

Another example of such suitable selective markers are the *ura3* and *leu2* genes which complements the corresponding defect genes of e.g. the yeast strain *Saccharomyces cerevisiae* YNG318.

The vector may also comprise a selectable marker which confers resistance to a drug, e.g. ampicillin, kanamycin, tetracyclin, chloramphenicol, neomycin, hygromycin or methotrexate. For filamentous fungi, selectable markers include amdS, pyrG, argB, niaD, sC, trpC, pyr4, and DHFR.

To direct the polypeptide in question into the secretory pathway of the recombination host cell, a secretory signal sequence (also known as a leader sequence, prepro sequence or pre sequence) may be provided in the recombinant vector. The secretory signal sequence is joined to the DNA sequence encoding the lipolytic enzyme in the

correct reading frame. Secretory signal sequences are commonly positioned 5' to the DNA sequence encoding the polypeptide. The secretory signal sequence may be the signal normally associated with the polypeptide in question or may be from a gene encoding another  
5 secreted protein.

The signal peptide may be naturally occurring signal peptide, or a functional part thereof, or it may be a synthetic peptide. For secretion from yeast cells, suitable signal peptides have been found  
10 to be the a-factor signal peptide (cf. US 4,870,008), the signal peptide of mouse salivary amylase (cf. O. Hagenbuchle et al., (1981), Nature 289, 643-646), a modified carboxypeptidase signal peptide (cf. L.A. Valls et al., (1987), Cell 48, 887-897), the *Humicola lanuginosa* lipase signal peptide, the yeast BAR1 signal  
15 peptide (cf. WO 87/02670), or the yeast aspartic protease 3 (YAP3) signal peptide (cf. M. Egel-Mitani et al., (1990), Yeast 6, 127-137).

For efficient secretion in yeast, a sequence encoding a leader  
20 peptide may also be inserted downstream of the signal sequence and upstream of the DNA sequence encoding the polypeptide in question. The function of the leader peptide is to allow the expressed polypeptide to be directed from the endoplasmic reticulum to the Golgi apparatus and further to a secretory vesicle for secretion  
25 into the culture medium (i.e. exportation of the polypeptide across the cell wall or at least through the cellular membrane into the periplasmic space of the yeast cell). The leader peptide may be the yeast a-factor leader (the use of which is described in e.g. US 4,546,082, EP 16 201, EP 123 294, EP 123 544 and EP 163 529).  
30 Alternatively, the leader peptide may be a synthetic leader peptide, which is to say a leader peptide not found in nature. Synthetic leader peptides may, for instance, be constructed as described in WO 89/02463 or WO 92/11378.

35 For use in filamentous fungi, the signal peptide may conveniently be derived from a gene encoding an *Aspergillus* sp. amylase or glucoamylase, a gene encoding a *Rhizomucor miehei* lipase or protease, a *Humicola lanuginosa* lipase. The signal peptide is preferably derived from a gene encoding *A. oryzae* TAKA amylase, *A.*  
40 *niger* neutral  $\alpha$ -amylase, *A. niger* acid-stable amylase, or *A. niger*

glucoamylase.

The recombination host cell

5 The recombination host cell, into which the mixture of plasmid/fragment DNA sequences are to be introduced, may be any eukaryotic cell, including fungal cells and plant cells, capable of recombining the homologous DNA sequences in question.

10 According to prior art prokaryotic microorganisms, such as bacteria including *Bacillus* and *E. coli*; eukaryotic organisms, such as filamentous fungi, including *Aspergillus* and yeasts such as *Saccharomyces cerevisiae*; and tissue culture cells from avian or mammalian origins have been suggested for *in vivo* recombination. All of said organisms can be used as recombination host cell, but in  
15 general prokaryotic cells are not sufficiently effective (i.e. does not result in a sufficient number of variants) to be suitable for recombination methods for industrial use.

20 Consequently, preferred recombination host cells according to the present invention are fungal cells, such as yeast cells or filamentous fungi.

Examples of suitable yeast cells include cells of *Saccharomyces* sp., in particular strains of *Saccharomyces cerevisiae* or *Saccharomyces*  
25 *kluveri* or *Schizosaccharomyces* sp., Methods for transforming yeast cells with heterologous DNA and producing heterologous polypeptides therefrom are described, e.g. in US 4,599,311, US 4,931,373, US 4,870,008, 5,037,743, and US 4,845,075, all of which are hereby incorporated by reference. Transformed cells may be selected by,  
30 e.g., a phenotype determined by a selectable marker, commonly drug resistance or the ability to grow in the absence of a particular nutrient, e.g. leucine. A preferred vector for use in yeast is the POT1 vector disclosed in US 4,931,373. The DNA sequence encoding the polypeptide may be preceded by a signal sequence and optionally a  
35 leader sequence, e.g. as described above. Further examples of suitable yeast cells are strains of *Kluyveromyces*, such as *K. lactis*, *Hansenula*, e.g. *H. polymorpha*, or *Pichia*, e.g. *P. pastoris* (cf. Gleeson et al., (1986), J. Gen. Microbiol. 132, 3459-3465; US 4,882,279).

40

Examples of other fungal cells are cells of filamentous fungi, e.g. *Aspergillus* sp., *Neurospora* sp., *Fusarium* sp. or *Trichoderma* sp., in particular strains of *A. oryzae*, *A. nidulans* or *A. niger*. The use of *Aspergillus* sp. for the expression of proteins is described in, e.g., EP 272 277, EP 230 023. The transformation of *F. oxysporum* may, for instance, be carried out as described by Malardier et al., (1989), Gene 78, 147-156.

In a preferred embodiment of the invention the recombination host cell is a cell of the genus *Saccharomyces*, in particular *S. cerevisiae*.

#### METHODS AND MATERIALS

##### DNA sequence:

*Humicola lanuginosa* DSM 4109 derived lipase encoding DNA sequence.

*Humicola lanuginosa* lipase variants:

Variants used for preparing vectors to be opened with *Nru*I in Example 2:

- (a) E56R, D57L, I90F, D96L, E99K
- (b) E56R, D57L, V60M, D62N, S83T, D96P, D102E
- (c) D57G, N94K, D96L, L97M
- (d) E87K, G91A, D96R, I100V, E129K, K237M, I252L, P256T, G263A, L264Q
- (e) E56R, D57G, S58F, D62C, T64R, E87G, G91A, F95L, D96P, K98I, (K237M)
- (f) E210K

Variants used for preparing DNA fragments by standard PCR amplification in Example 2:

- (g) S83T, N94K, D96N
- (h) E87K, D96V
- (i) N94K, D96A
- (j) E87K, G91A, D96A
- (k) D167G, E210V
- (l) S83T, G91A, Q249R
- (m) E87K, G91A
- (n) S83T, E87K, G91A, N94K, D96N, D111N.
- (o) N73D, E87K, G91A, N94I, D96G.
- (p) L67P, I76V, S83T, E87N, I90N, G91A, D96A, K98R.



- (q) S83T, E87K, G91A, N92H, N94K, D96M  
(s) S85P, E87K, G91A, D96L, L97V.  
(t) E87K, I90N, G91A, N94S, D96N, I100T.  
(u) I34V, S54P, F80L, S85T, D96G, R108W, G109V, D111G, S116P, L124S,  
5 V132M, V140Q, V141A, F142S, H145R, N162T, I166V, F181P, F183S,  
R205G, A243T, D254G, F262L.  
(v) E56R, D57L, I90F, D96L, E99K  
(x) E56R, D57L, V60M, D62N, S83T, D96P, D102E  
(y) D57G, N94K, D96L, L97M  
10 (z) E87K, G91A, D96R, I100V, E129K, K237M, I252L, P256T, G263A, L264Q  
(aa) E56R, D57G, S58F, D62C, T64R, E87G, G91A, F95L, D96P, K98I

Strains:Expression system host:

- 15 *Saccharomyces cerevisiae* YNG318: MATa Dpep4[cir'] ura3-52, leu2-D2,  
his 4-539  
*Saccharomyces cerevisiae* Rad52: Strain M1533 = MATa rad52 ura3,  
obtained from Torsten Nilsson Tillgren, Institute of Genetics,  
University of Copenhagen.

20

Plasmids:

pJSO26 (see figure 3)  
pJSO37 (see figure 4)  
pYES 2.0 (Invitrogen)

25

Transformation selective marker

ura3  
leu2

30 Media

SC-ura<sup>-</sup>: 90 ml 10 x Basal salt, 22.5 ml 20% casamino acids, 9 ml 1%  
tryptophan, H<sub>2</sub>O ad 806 ml, autoclaved, 3.6 ml 5% threonine and 90 ml  
20% glucose or 20% galactose added.

- LB-medium: 10 g Bacto-tryptone, 5 g Bacto yeast extract, 10 g NaCl  
35 in 1 litre water.

Brilliant Green (BG) (Merck, art. No. 1.01310)

BG-reagent: 4 mg/ml Brilliant Green (BG) dissolved in water

Substrate 1:

- 10 ml olive oil (Sigma CAT NO. 0-1500)  
40 20 ml 2% polyvinyl alcohol (PVA)

The Substrate is homogenised for 15-20 minutes.

Methods:

5 Construction of yeast expression vector

The expression plasmids pJSO26 and pJSO37, are derived from pYES 2.0. The inducible GAL1-promoter of pYES 2.0 was replaced with the constitutively expressed TPI (triose phosphate isomerase)-promoter from *Saccharomyces cerevisiae* (Albert and Karwasaki, (1982), J. Mol. Appl Genet., 1, 419-434), and the ura3 promoter has been deleted. A restriction map of pJSO26 and pJSO37 is shown in figure 3 and figure 4, respectively.

Preparation of the wild-type DNA fragment

15 A lipase wild-type DNA fragment can be prepared either by PCR amplification (resulting in low, medium or high mutagenesis), of the pJSO26 plasmid or by cutting the DNA fragment out by digesting with a suitable restriction enzyme.

20 Fermentation of *Humicola lanuginosa* lipase variants in yeast

10 ml of SC-ura<sup>-</sup> medium is inoculated with a *S. cerevisiae* colony and grown at 30°C for 2 days. The 10 ml is used for inoculating 300 ml SC-ura<sup>-</sup> medium which is grown at 30°C for 3 days. The 300 ml is used for inoculation 5 l of the following G-substrate:

25 400 g Amicase  
6.7 g yeast extract (Difco)  
12.5 g L-Leucin (Fluka)  
6.7 g (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>  
10 g MgSO<sub>4</sub>·7H<sub>2</sub>O  
30 17 g K<sub>2</sub>SO<sub>4</sub>  
10 ml Trace compounds  
5 ml Vitamin solution  
6.7 ml H<sub>3</sub>PO<sub>4</sub>  
25 ml 20% Pluronic (antifoam)

35

In a total volume of 5000 ml:

The yeast cells are fermented for 5 days at 30°C. They are given a start dosage of 100 ml 70% glucose and added 400 ml 70% glucose/day. A pH=5.0 is kept by addition of a 10% NH<sub>3</sub> solution. Agitation is 300 rpm for the first 22 hours followed by 900 rpm for the rest of the fermentation. Air is given with 1 l air/l/min for the first 22 hours

40

followed by 1.5 l air/l/min for the rest of the fermentation.

Trace compounds:

- 6.8 g      ZnCl<sub>2</sub>  
5    54.0 g      FeCl<sub>2</sub>·6H<sub>2</sub>O  
19.1 g      MnCl<sub>2</sub>·4H<sub>2</sub>O  
2.2 g      CuSO<sub>4</sub>·5H<sub>2</sub>O  
2.58 g      CoCl<sub>2</sub>  
0.62 g      H<sub>3</sub>BO<sub>3</sub>  
10    0.024 g      (NH<sub>4</sub>)<sub>6</sub>Mo<sub>7</sub>O<sub>24</sub>·4H<sub>2</sub>O  
0.2 g      KI  
100 ml      HCl (concentrated)  
In a total volume of 1 l.

15    Vitamin solution:

- 250 mg      Biotin  
3 g          Thiamin  
10 g          D-Calciumpanthetonat  
100 g          Myo-Inositol  
20    50 g          Cholinchlorid  
1.6 g          Pyridoxin  
1.2 g          Niacinamid  
0.4 g          Folicacid  
0.4 g          Riboflavin  
25    In a total volume of 1l.

Transformation of yeast

- Saccharomyces cerevisiae* is transformed by standard methods (cf. Sambrooks et al., (1989), Molecular Cloning: A Laboratory Manual, 2nd Ed., Cold Spring Harbor)
- 30

Determination of yeast transformation frequency

- The transformation frequency is determined by cultivating the transformants on SC-ura<sup>-</sup>plates for 3 days and counting the number of colonies appearing. The number of transformants per mg opened plasmid is the transformation frequency.
- 35

Screening for positive variants with improved wash performance

- The following filter assay can be used for screening positive variants with improved wash performance.
- 40

#### Low calcium filter assay

- 1) Provide SC Ura<sup>r</sup> replica plates (useful for selecting strains carrying the expression vector) with a first protein binding filter (Nylon membrane) and a second low protein binding filter (Cellulose acetate) on the top.
- 2) Spread yeast cells containing a parent lipase gene or a mutated lipase gene on the double filter and incubate for 2 or 3 days at 30°C.
- 3) Keep the colonies on the top filter by transferring the top-filter to a new plate.
- 4) Remove the protein binding filter to an empty petri dish.
- 5) Pour an agarose solution comprising an olive oil emulsion (2% PVA:olive oil=3:1), Brilliant green (indicator, 0.004%), 100 mM tris buffer pH9 and EGTA (final concentration 5mM) on the bottom filter so as to identify colonies expressing lipase activity in the form of blue-green spots.
- 6) Identify colonies found in step 5) having a reduced dependency for calcium as compared to the parent lipase.

DNA sequencing was performed by using applied Biosystems ABI DNA sequence model 373A according to the protocol in the ABI Dye Terminator Cycle Sequencing kit.

#### 25 Assessing the efficiency of recombination

The number of colonies determines the efficiency of the opened vector and fragment recombination. The percentage of colonies with active lipase activity gives an estimate of the mixing of the active and inactive genes - theoretically it can be calculated for one frameshift that the closer to 50% the better mixing if equal likelihood of wild type and frameshift, 25% for 2 frameshifts and 12.5% for 3 frameshifts.

#### Frameshift mutation

- 35 The frameshift mutation were created either by filling in a restriction site (in case of 5' overhang) or deleting the "sticky ends" (in case of 3' overhang) by T4 DNA polymerase with or without dNTP (deoxynucleotides = equal amounts of dATP, dTTP, dCTP and dGTP). Methods for filling in of restriction sites (referred to as "F" on Figure 7) and deleting the sticky ends (referred to as "(D)" on Figure 7) are well known in the art.

Method for assessing colonies with lipase activity

The number of colonies and positives (i.e. with lipase activity) are calculated as the average of 3 plates.

- 5 The cultivation condition and screening condition used is the following:
- 1) Provide SC Ura-plates with a protein binding filter (Nylon filter) onto the plate.
  - 10 2) Spread yeast cells containing a parent lipase gene or a mutated lipase gene on the filter and incubate for 3 or 4 days at 30°C.
  - 3) Remove the protein binding filter with the colonies to a petri dish containing: An agarose solution comprising an olive oil emulsion (2% PVA:Olive oil=2:1), Brilliant green (indicator, 0.004%), 100 mM tris buffer pH 9.
  - 15 5) Identify colonies expressing lipase activity in the form of blue-green spots.

EXAMPLES

20 Example 1

Testing in vivo recombination of two homologous genes

25 The *Saccharomyces cerevisiae* expression plasmid pJSO26 was constructed as described above in the "Material and Methods"-section.

A synthetic *Humicola lanuginosa* lipase gene (in pJSO37) containing 12 additional restriction sites (see figure 4) was cut with NruI, 30 PstI, and NruI and PstI, respectively, to open the gene approximately in the middle of the DNA sequence encoding the lipase.

The opened plasmid (pJSO37) was transformed into *Saccharomyces cerevisiae* YNG318 together with an about 0.9 kb wild-type *Humicola lanuginosa* lipase DNA fragment (see figure 1) prepared from pJSO26 35 by PCR amplification.

Further, the opened plasmid was also transformed into the yeast recombination host cell alone (i.e. without the 0.9 kb synthetic 40 lipase DNA fragment).

The transformed yeast cells were grown as described in the "Ma-

terials and Method"-section above, and the transformation frequency was determined as described above.

It was found that the transformation frequency of the opened plasmid alone was very low (10 transformants per mg opened plasmid), in comparison to the transformation frequency of said plasmid/fragment (50,000 transformants per mg opened plasmid).

The plasmid/fragment was PCR amplified resulting in 20 transformants containing fragments covering the lipase gene region of the recombined plasmid/fragments. The recombination mixture of the 20 transformants were analyzed by restriction site digestion using standard methods. The result is displayed in Table 1.

Table 1

| PCR<br>fragment | SphI | HindIII | PstI | NruI (not tested) |     |        |      |      |
|-----------------|------|---------|------|-------------------|-----|--------|------|------|
|                 |      |         |      | BstXI             | NhI | BstEII | KpnI | XhoI |
| P1              | wt   | wt      | wt   | wt                | wt  | wt     | wt   | wt   |
| P2              | sg   | sg      | sg   | wt                | wt  | wt     | wt   | wt   |
| P3              | sg   | sg      | sg   | sg                | nd  | sg     | sg   | nd   |
| P4              | nd   | sg      | sg   | wt                | nd  | wt     | nd   | nd   |
| P5              | wt   | wt      | nd   | wt                | wt  | wt     | wt   | wt   |
| P6              | sg   | sg      | sg   | sg                | sg  | sg     | sg   | nd   |
| N1              | wt   | wt      | wt   | wt                | sg  | wt     | wt   | wt   |
| N2              | wt   | wt      | wt   | wt                | wt  | wt     | wt   | wt   |
| N3              | wt   | wt      | wt   | wt                | wt  | wt     | wt   | wt   |
| N4              | sg   | sg      | sg   | wt                | wt  | wt     | wt   | wt   |
| N5              | sg   | sg      | sg   | wt                | wt  | wt     | wt   | wt   |
| N6              | wt   | wt      | wt   | sg                | sg  | sg     | sg   | sg   |
| P/N1            | sg   | sg      | sg   | wt                | wt  | wt     | wt   | wt   |
| P/N2            | sg   | sg      | sg   | sg                | sg  | sg     | sg   | nd   |
| P/N3            | sg   | sg      | sg   | wt                | nd  | sg     | sg   | sg   |
| P/N4            | sg   | sg      | sg   | sg                | sg  | sg     | sg   | nd   |
| P/N5            | sg   | sg      | sg   | sg                | sg  | sg     | sg   | nd   |
| P/N6            | sg   | sg      | sg   | wt                | nd  | sg     | sg   | sg   |
| P/N7            | nd   | wt      | wt   | wt                | nd  | wt     | nd   | wt   |
| P/N8            | sg   | sg      | sg   | wt                | wt  | wt     | sg   | nd   |

P: plasmid opened with PstI  
 N: Plasmid opened with NruI  
 P/N: plasmid opened with PstI and NruI (resulting in the removal of a 75 bp fragment)  
 wt: wild-type gene restriction enzyme pattern  
 sg: synthetic gene restriction enzyme pattern  
 nd: not determined

As can be seen from Table 1 10 transformants (equivalent to 50%)

contained recombined DNA sequences. 4 of these 10 DNA sequences (equivalent to 20%) contained either a region of the wild-type gene recombined into the synthetic gene or a region of the synthetic gene recombined into the wild-type fragment.

5

## Example 2

### In vivo recombination of *Humicola lanuginosa* lipase variants

The DNA sequences of 20 variants of the *Humicola lanuginosa* lipase were in vivo recombined in the same mixture.

10

Six vectors were prepared from the lipase variants (a) to (f) (see the list above) by ligation into the yeast expression vector pJSO37. All vectors were cut open with NruI.

15

DNA fragment of all 20 homologous DNA sequences (g) to (aa) (see the list above) were prepared by PCR amplification using standard methods.

The 20 DNA fragments and the 6 opened vectors were mixed and transformed into the yeast *Saccharomyces cerevisiae* YNG313 by standard methods. The recombination host cell was cultivated as described above and screened as described above. About 20 transformants were isolated and tested for improved wash performance using the filter assay method described in the "Material and Methods"-section.

25

Two positive transformants (named A and B) were identified using the filter assay.

30

In comparison to the wild-type amino acid sequence the two recombined positive transformants had the following mutations.

A: D57G, N94K, D96L, P256T  
 ---- ---- ---- =====  
 A is a recombination of two variants.  
 ---- originates from the vector (d)  
 ===== originates from the DNA fragment prepared from variant (y)

B: D57G, G59V, N94K, D96L, L97M, S116P, S170P, N249R  
 ---- ??? ???? <<<< ???? =====

B is a recombination of vector (c), DNA fragments (n) and (u).

35

40

---- originates from the vector (c)  
<<<< originates from the DNA fragment prepared from variant (u)  
==== originates from the DNA fragment prepared from variant (n)  
???? Amino acid mutation which is not a result of recombination.

5  
As can be seen the resulting positive variants have been formed by recombination two or more variants. The amino acid mutations marked "?????" are not a result of *in vivo* recombination, as none of the shuffled lipase variants (see the list above) comprise any of said mutations. Consequently, these mutations are a result of random mutagenesis arisen during preparation of the DNA fragments by standard PCR amplification.

15 Example 3

Recombination with one frameshift mutations

20 Synthetic *Humicola lanuginosa* lipase gene (in vector JSO37) was made inactive at various positions by deleting (positions 184/385) or filling-in (position 290/317/518/746) restriction enzyme sites or by site-directed introduction of a stop codon. All inactive synthetic lipase genes of 900 bp can be deduced from Figure 7).

25 A number of different 900 bp DNA fragments were made from the above vectors using primer 4699 and primer 5164 using standard PCR technique. Smaller PCR fragments were made using primer 8487 and primer 4548 (260bp), primer 2843 and primer 4548 (488bp).

30 0.5 ml (app. 0.1 mg) of vectors Blue 425, Blue 426, Blue 428 and Blue 429, opened with Pst I (i.e. position 385), vectors Blue 424 and Blue 425 opened with NruI (i.e. position 464) were together with 3 ml (app. 0.5 mg) of fragments 424, 425, 426, 428, 429 in various combination transformed into 100 ml *Saccharomyces cerevisiae*

35 YNG318 competent cells as displayed in Table 1A.

The number of colonies and positives (i.e. with lipase activity) were calculated as the average of 3 plates as described in the Material and Methods section.

40  
The result of the test is shown in Table 1A



Table 1A

| vector + Fragment         | Number of colonies | % of colonies with active lipase activity |
|---------------------------|--------------------|---|
| 1. Blue 428 + 429▣        | 774                | 16%                                       |
| 2. Blue 429 + 428#        | 645                | 3%  |
| 3. Blue 426 + 425#        | 276                | 25%                                       |
| 4. Blue 425 + 426         | 528                | 18%                                       |
| 5. Blue 425/Nru I + 426   | 539                | 28%                                       |
| 6. Blue 425 + 424         | 139                | 7%  |
| 7. Blue 424/NruI + 425▣   | 74                 | 32%                                       |
| 8. Blue 428 + 425         | 81                 | 12%                                       |
| 9. Blue 428 + wt fragment | 317                | 37%                                       |

5 Pairwise recombinations of one frameshift mutation on the vector and another on the fragment on the opposite side of the opening site. ▣ determined by 9 plates; # determined by 6 plates.

10 The first 2 rows of Table 1A displays vectors and fragments with a frameshift on each side of the PstI site. The "mirror image" experiment in row 2 compared to row 1 gives a reproducible lower number of active colonies. The same is true for row 3 and 4 even though it is not as pronounced. Moving the opening site closer to the frameshift in the vector increases the number of actives as seen in row 5. This can explain the reason for the difference in the "mirror image" experiments. In both cases the higher number of  
15 positives has the opening site closer to the frameshift in the vector.

20 It can therefore be concluded that the closer the mutation is to the end of the vector the higher chance of mixing. This is probably arising from the well known fact that free DNA ends have a high recombinogenic potential. Therefore it is desirable to have as many free DNA ends as possible to increase the mixing of the genes. This is for example obtained in the later example with recombination of multiple overlapping fragments.

25

Row 6 has a rather low number of actives probably due to the location of the frameshift on the fragment exactly at the PstI opening site of the vector.

Row 7 has the frameshift of the vector close to the opening site and again it gives a high number of actives.

#### Recombination with one stop codon mutantions

- 5 In order to test if there are any difference in the recombination efficiency of stop codon mutations compared to frameshift mutations the following experiments were made..

- 10 The same way as described above 0.5 ml (app. 0.1 mg) vectors Blue 624, Blue 625 and Blue 626 (see Table 1B) opened with PstI comprising stop codons at specified positions (positions 184, 317 and 746, respectively) (perpared by site-directed mutagenesis) were together with 3 ml (app. 0.5 mg) of fragments 624, 625 and 626 transformed into 100 ml *Sacchchromyces cerevisiae* YNG318 competent cells in varios combination as displayed in Table 1B.

Table 1B

| Vector +<br>Fragment | Number of<br>colonies | % of colonies with lipase<br>activity |
|----------------------|-----------------------|---------------------------------------|
| 1. Blue 626 +<br>624 | ND                    | 40%                                   |
| 2. Blue 624 +<br>626 | ND                    | 12%                                   |
| 3. Blue 625 +<br>624 | ND                    | 75%                                   |
| 4. Blue 624 +<br>625 | ND                    | 10%                                   |

- 20 Pairwise recombinations of one stop codon mutation on the vector and another on the fragment on the opposite side of the opening site. ND = not determined but a high number.

- 25 Row 1 and 2 (in Table 1B) have the mutations located at the same place as row 1 and 2 in Table 1A. As can be seen the number of colonies with lipase activity is clearly higher for the stop codon mutations compared to the frameshift mutations, but the same relative difference between the "mirror image" experiments.

- 30 This might indicate that the stop codon mutations, which is closer to the "application" of the method, gives a better mixing than frameshift mutations. Row 3 and 4 confirms that the closer the mutation is to the end of the vector the higher chance of mixing.

#### Recombination with one or two frameshift mutation in th vector

and one or two frameshift mutations in the fragment

Using the same approach as described above the influence of one or two frameshift mutations in the vector and one or two frameshift mutations in the fragment were tested using vectors Blue 425, 426 and 428 (one mutation) and vectors Blue 442, Blue 443 (two mutations) and fragments 442 and 443 (two frameshift mutations) and fragments 424, 425, 426, 427, 428 (one mutation) and wild-type (no mutation)

10

The vectors Blue 442 and 443 are double frameshift mutations: Blue 442 = 428+429 and blue 443 = 427+429 (see Figure 7).

Recombination was performed by transforming 0.5 ml vector (app. 0.1 mg) opened with PstI and 3 ml PCR-fragment (app. 0.5 mg) into 100 ml *Saccharomyces cerevisiae* YNG318 competent cells.

15

The result of the test is shown in Table 2A and Table 2B

20

Table 2A

| Vector + Fragment  | Number of colonies | % of colonies with active Lipolase |
|--------------------|--------------------|------------------------------------|
| 1. Blue 425 + 442  | 142                | 15%                                |
| 2. Blue 425 + 443  | 144                | 14%                                |
| 3. Blue 426 + 442  | 42                 | 42%                                |
| 4. Blue 426 + 443# | 77                 | 20%                                |
| 5. Blue 428 + 443  | 115                | 3.8%                               |

One frameshift mutation on the vector and two on the fragment on each side of the opening site. # determined by 6 plates.

25

Table 2B

| Vector + Fragment | Number of colonies | % of colonies with active Lipolase |
|-------------------|--------------------|------------------------------------|
| Blue 442 + 424    | 137                | 0.5%                               |
| Blue 442 + 426    | 118                | 1.1%                               |
| Blue 442 + 427#   | 125                | 1.3%                               |
| Blue 443 + 425    | 540                | 2.5%                               |

|                        |     |       |
|------------------------|-----|-------|
| Blue 443 + 426         | 196 | 1.5%  |
| Blue 443 + 428         | 469 | 3.1%  |
| Blue 442 + wt fragment | 135 | 7.7%  |
| Blue 443 + wt fragment | 488 | 10.7% |

Two frameshift mutations on the vector on each side of the opening site and one on the fragment. # determined by 6 plates.

Table 2A shows a rather high number of colonies with lipase activity even with a total of 3 frameshifts (but only one frameshift on the vector) except for the last row where the frameshift on the vector is located far from the opening site. Lane 4 has fewer actives than lane 3 probably due to that the frameshift on the vector is located further away from the opening site than the frameshift on the fragment making the active genes mosaics that are not related to the opening site (see figure 2A). In Table 2B a very low number of actives are observed when there are 2 frameshifts located on the vector. Most of these active colonies are mosaics of the "parent" DNA meaning that the mixing is not related to the opening site (see figure 2B).

#### Recombination with two different vectors or fragments

The result of recombination with two different vectors or fragments the test is shown in Table 3

Table 3

| Vector + Fragment                 | Number of colonies | % of colonies with active Lipolase |
|-----------------------------------|--------------------|------------------------------------|
| Blue 428/pstI + Blue 429/pst #    | 13                 | 15%                                |
| Blue428/pst + Blue 429/PstI + 442 | 273                | 4.2%                               |
| Blue 442/pstI + 428 + 429         | 228                | 0.8%                               |
| Blue 443/pstI + 427 + 428         | 229                | 1.6%                               |

Recombinations with 2 different vectors or fragments. # Determined by 1 plate.

A low number of colonies are seen for the control experiment in row 1 of table 3 as expected. The fragment added in the middle row has

two frameshifts each corresponding to the frameshift on each vector. Via a tripartite recombination 4.2% actives are created. With two fragments with each one frameshifts and a vector with the same two frameshifts very few actives are found.

5

#### Recombination with vectors opened at different sites

Opening the vector in one side instead of approximately in the middle still gives good recombination as shown in Table 4. Two vectors opened at different sites can also recombine to some extent (compare with the vector controls in table 13).

10

Table 4

| Vector + Fragment          | Number of colonies | % of colonies with active Lipolase |
|----------------------------|--------------------|------------------------------------|
| Blue 428/xho + 429         | 160                | 11%                                |
| Blue 428/xho+Blue 429/pst# | 35                 | 6.3%                               |

15 Opening of the vector in one side instead of in the middle. # determined by 6 plates.

#### Recombination at different concentrations of vector and fragment

20

The relative concentration of vector to fragment do influence the percentage of positive colonies as can be seen in Table 5.

Table 5

| Vector + Fragment        | Number of colonies | % of colonies with lipase activity |
|--------------------------|--------------------|------------------------------------|
| 0.5µl Blue 426 + 3µl 442 | 42                 | 42%                                |
| 1.5µl Blue 426 + 3µl 442 | 21                 | 51%                                |
| 1.5µl Blue 426 + 9µl 442 | 34                 | 26%                                |
| 1.5µl Blue 426 + 3µl 427 | 230                | 2.8%                               |
| 1µl Blue 442 + 1µl 425   | 224                | 1.16%                              |
| 1µl Blue 442 + 2µl       | 429                | 0.9%                               |

|                            |     |      |
|----------------------------|-----|------|
| 425                        |     |      |
| 1μl Blue 442 + 4μl<br>425  | 434 | 1.6% |
| 1μl Blue 442 + 8μl<br>425  | 481 | 1.6% |
| 1μl Blue 442 + 16μl<br>425 | 497 | 2.0% |

Varying the concentration of the vector or fragment.

#### 5 Recombination with fragments of different size

The size of the fragment also influences the recombination result as seen in Table 6.

10

Table 6

| Vector + Fragment         | Number of colonies | % of colonies with active Lipolase |
|---------------------------|--------------------|------------------------------------|
| Blue 424 + 425<br>(260bp) | 73                 | 34%                                |
| Blue 424 + 425<br>(489bp) | 130                | 45%                                |
| Blue 424 + 424<br>(480bp) | 133                | 0.3%                               |
| Blue 424 + 428<br>(480bp) | 130                | 36%                                |
| Blue 428 + 425<br>(480bp) | 150                | 28%                                |
| Blue 425 + 424<br>(480bp) | 69                 | 0%                                 |
| Blue 425 + 428<br>(480bp) | 63                 | 55%                                |

Recombination with smaller fragments than 900 bp.

15

#### Recombination with unopened vectors

Transformation with unopened vectors shows a very low degree of recombination (Table 7).

Table 7

| Plasmid                | Number of colonies | % of colonies with active Lipolase |
|------------------------|--------------------|------------------------------------|
| Blue 428 + Blue<br>429 | 887                | 0.3%                               |

|                        |     |      |
|------------------------|-----|------|
| Blue 426 + Blue<br>425 | 697 | 0.7% |
|------------------------|-----|------|

Recombination of unopened plasmids.

#### Example 4

5

#### Test of *S. cerevisiae* mutants altered in recombination

Using the same approach as described in Example 3 recombination of opened and unopened vectors and fragments were tested using a *Saccharomyces cerevisiae* rad52 mutant as the recombination host cell. The result is displayed in Table 8.

10

Table 8

| Vector +<br>Fragment | Number of<br>colonies | % of colonies with active<br>Lipolase |
|----------------------|-----------------------|---------------------------------------|
| Blue 428 + 429       | 0                     | 0                                     |
| Blue 442 + 427       | 0                     | 0                                     |
| Blue 424 + 425       | 0                     | 0                                     |
| Blue 426 + 443       | 0                     | 0                                     |
| Plasmid pJSO<br>37   | 544                   | 100%                                  |

Recombination result in *rad52* mutant.

The result with *rad52* showed that recombination was completely abolished. The RAD52 function is required for classical recombination (but not for unequal sister-strand mitotic recombination) showing that the recombination of opened vector and fragment could involve a classical recombination mechanism.

20

#### Example 6

#### Recombination of multiple partial overlapping fragments

25

In order to increase the mixing of the mutations by the recombination method of the invention, recombination of two fragments and one gapped vector were attempted.

30

Table 15

| Vector + Fragment                         | Number of<br>colonies | % of colonies with lipase<br>activity |
|---|-----------------------|---------------------------------------|
| 1. pJSO37/HindIII-XhoI<br>+ PCR319+PCR327 | > 2000                | 100%                                  |
| 2. pJSO37/HindIII-XhoI<br>+ PCR321+PCR331 | ≈ 2000                | ≈ 0.2%                                |

|   |        |       |
|---|--------|-------|
| 3. pJSO37/HindIII-XhoI + PCR319+PCR331    | ≈ 1500 | ≈ 1%  |
| 4. pJSO37/HindIII-XhoI + PCR319+PCR386    | > 5000 | > 90% |
| 5. pJSO37/HindIII-XhoI + PCR321+PCR386    | > 5000 | ≈ 25% |
| 6. Blue 428/HindIII-XhoI + PCR321+PCR331  | 400    | 0.2%  |
| 7. Blue 428/HindIII-XhoI + PCR319+PCR327  | ≈ 1500 | > 90% |
| 8. Blue 428/HindIII-XhoI + PCR321+PCR327  | ≈ 150  | ≈ 10% |
| 9. Blue 428/HindIII-XhoI + PCR327+PCR385  | ≈ 1500 | ≈ 10% |
| 10. Blue 429/HindIII-XhoI + PCR319+PCR386 | ≈ 400  | ≈ 15% |
| 11. Blue 429/HindIII-XhoI + PCR321+PCR386 | ≈ 350  | ≈ 15% |
| 12. Blue 442/HindIII-XhoI + PCR319+PCR327 | ≈ 1500 | ≈ 10% |
| 13. Blue 428/HindIII-XhoI +               | 2      | 0     |
| 14. Blue 429/HindIII-XhoI +               | 0      | 0     |
| 15. Blue 442/HindIII-XhoI +               | 6      | 0     |
| 16. Blue 428/HindIII-XhoI + PCR331        | 4      | 0     |
| 17. Blue 428/HindIII-XhoI + PCR321        | 2      | 0     |

Recombination result of two fragments and a gapped vector. The last 5 rows are controls.

5 As can be seen in Table 15, the recovery of the *Humicola lanuginosa* lipase gene is very efficient. The last 5 rows in Table 15 shows that the opened vector alone or with only one fragment not covering the whole gap (see figure 3) gives only very few colonies.

10 The first row is with wild type fragments gives 100% of active colonies.

The second row is with two fragments each containing a frameshift. The fragment PCR331 fragment has the frameshift located at the BglII site which, in this recombination, is not covered by a wild



type fragment (see figure 3) and therefore gives about 0% of active lipase. The same is the case for row 3 and 6.

- 5 In the row 4, fragment PCR386 containing a frameshift at the SphI site which is overlapped by wild type sequences in the gapped vector. The frameshift was recombined into less than 10% of the genes which is lower than the result for one fragment recombination in the last row of Table 1A above.
- 10 In row 5 a rather high mixing is observed between the 2 fragments each containing a frameshift and the wild type gapped vector giving 25% active and 75% inactive lipase colonies. This is probably due to that the fragment PCR321 has the frameshift in the overlap between the 2 fragments and in the gapped region of the vector. If
- 15 fragment PCR386 contributes to 10% inactives like in row 4, fragment PCR321 gives the remaining 65% inactives - therefore PCR386 gives 35% wt in the overlap.
- 20 Row 7 is the "mirror image" of row 4 with the frameshift at the SphI site on the vector (see Figure 7) and 2 wild type fragments giving an integration of the wild type fragment into more than 90% of the vectors.
- 25 Row 8 shows like in row 5 that the frameshift of PCR321 in the overlap and gap region gives a very high number of inactive.
- In row 9, fragment PCR385 with a frameshift in the vector overlap, causes a very high number of inactives.
- 30 Row 10 gives a rather high number of inactives compared to row 7 and 4. It is not increased in row 11.
- Row 12 shows that two frameshifts on the vector gives a lower number of actives compared to one in row 7.
- 35 The recombination of 3 partial overlapping fragments into a gapped vector is also very efficient as seen in Table 16. The last row with the vector alone gives very few colonies. As can be seen in figure 4 all fragments used are wt. In the first row in table 16,
- 40 there are rather long overlaps between the vector and fragments, but in the middle row the overlap between PCR353 and 355 is only 10

bp long and it is still very efficiently recombined! This surprising result may be utilized for very easy domain shuffling of even distantly related genes. For example can 3 different domains from 10 different genes be made as PCR fragments, designed to have a 10 to 20 bp overlap by primer design and recombined together and subsequently screened for the best combination (1000 possible combinations).

Table 16

| Vector + Fragment                        | Number of colonies | % of colonies with active Lipolase |
|--|--------------------|------------------------------------|
| pJSO37/PvuII-SpeI + PCR353+PCR354+PCR367 | > 5000             | 100%                               |
| pJSO37/PvuII-SpeI + PCR353+PCR355+PCR367 | > 5000             | 100%                               |
| pJSO37/PvuII-SpeI                        | 20                 | 100%                               |

Recombination result of 3 fragments and a gapped vector. The last row is a control.

## SEQUENCE LISTING

## (1) GENERAL INFORMATION:

- 5 (i) APPLICANT:  
(A) NAME: Novo Nordisk A/S  
(B) STREET: Novo Alle  
(C) CITY: Bagsvaerd  
10 (E) COUNTRY: Denmark  
(F) POSTAL CODE (ZIP): DK-2880  
(G) TELEPHONE: +45 4444 8888  
(H) TELEFAX: +45 4449 3256  
(ii) TITLE OF INVENTION: Method for preparing polypeptide variants  
15 (iii) NUMBER OF SEQUENCES: 15  
(iv) (iv) COMPUTER READABLE FORM:  
(A) MEDIUM TYPE: Floppy disk  
(B) COMPUTER: IBM PC compatible  
20 (C) OPERATING SYSTEM: PC-DOS/MS-DOS  
(D) SOFTWARE: PatentIn Release #1.0, Version #1.30B (EPO)

## (2) INFORMATION FOR SEQ ID NO: 1:

- 25 (i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 20 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear  
30 (ii) MOLECULE TYPE: other nucleic acid  
(A) DESCRIPTION: /desc = "Primer 2843"  
(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 1:

ACAAACATTA CGTGACGGG

20

## (2) INFORMATION FOR SEQ ID NO: 2:

- 40 (i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 18 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear  
(ii) MOLECULE TYPE: other nucleic acid  
(A) DESCRIPTION: /desc = "Primer 4699"  
45 (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 2:

CGGTACCCGG GGATCCAC

18

## (2) INFORMATION FOR SEQ ID NO: 3:

- 50 (i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 18 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
55 (D) TOPOLOGY: linear  
(ii) MOLECULE TYPE: other nucleic acid  
(A) DESCRIPTION: /desc = "Primer 5164"  
(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 3:

60 AATTACATCA TGCGGCC

18

## (2) INFORMATION FOR SEQ ID NO: 4:

- (i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 21 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear  
5 (ii) MOLECULE TYPE: other nucleic acid  
(A) DESCRIPTION: /desc = "Primer 8487"  
(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 4:

CATTGCTCC GGCTGCAGGG A 21

10 (2) INFORMATION FOR SEQ ID NO: 5:

(i) SEQUENCE CHARACTERISTICS:  
15 (A) LENGTH: 60 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear  
(ii) MOLECULE TYPE: other nucleic acid  
(A) DESCRIPTION: /desc = "Primer 4548"  
20 (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 5:

GTGTTCCGCC GGTCTGTACG GTCAGGAATT CTGCAAAGC  
CCTGTTTCCG ACTCGGGGGG 60

25 (2) INFORMATION FOR SEQ ID NO: 6:

(i) SEQUENCE CHARACTERISTICS:  
30 (A) LENGTH: 21 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear  
(ii) MOLECULE TYPE: other nucleic acid  
(A) DESCRIPTION: /desc = "Primer 5576"  
35 (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 6:

GGTCTGTACG GTCAGGAATT C 21

(2) INFORMATION FOR SEQ ID NO: 7:

40 (i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 19 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear  
45 (ii) MOLECULE TYPE: other nucleic acid  
(A) DESCRIPTION: /desc = "Primer 5578"  
(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 7:

CGTTTCGGGT GACGGGGAC 19

50 (2) INFORMATION FOR SEQ ID NO: 8:

(i) SEQUENCE CHARACTERISTICS:  
55 (A) LENGTH: 18 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear  
(ii) MOLECULE TYPE: other nucleic acid  
(A) DESCRIPTION: /desc = "Primer 1596"  
60 (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 8:

GGAGCAAATG TCATTAT 18

(2) INFORMATION FOR SEQ ID NO: 9:

(i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 64 base pairs  
 (B) TYPE: nucleic acid  
 (C) STRANDEDNESS: single  
 (D) TOPOLOGY: linear  
 (ii) MOLECULE TYPE: other nucleic acid  
 (A) DESCRIPTION: /desc = "Primer 4545"  
 (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 9:

GCATTGGCAA CTGTTGCCGG AGCAGACCTG CGTGGAAATG  
 GGTATGATAT CGACGTGTTT TCAT

(2) INFORMATION FOR SEQ ID NO: 10:

(i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 876 base pairs  
 (B) TYPE: nucleic acid  
 (C) STRANDEDNESS: single  
 (D) TOPOLOGY: circular  
 (ii) MOLECULE TYPE: other nucleic acid  
 (A) DESCRIPTION: /desc = "Vector pJSO26"  
 (vi) ORIGINAL SOURCE:  
 (B) STRAIN: Humicola lanuginosa  
 (ix) FEATURE:  
 (A) NAME/KEY: CDS  
 (B) LOCATION:1..876  
 (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 10:

ATG AGG AGC TCC CTT GTG CTG TTC TTT GTC TCT GCG TGG ACG GCC TTG 48  
 Met Arg Ser Ser Leu Val Leu Phe Phe Val Ser Ala Trp Thr Ala Leu  
 1 5 10 15

GCC AGT CCT ATT CGT CGA GAG GTC TCG CAG GAT CTG TTT AAC CAG TTC 96  
 Ala Ser Pro Ile Arg Arg Glu Val Ser Gln Asp Leu Phe Asn Gln Phe  
 20 25 30

AAT CTC TTT GCA CAG TAT TCT GCA GCC GCA TAC TGC GGA AAA AAC AAT 144  
 Asn Leu Phe Ala Gln Tyr Ser Ala Ala Ala Tyr Cys Gly Lys Asn Asn  
 35 40 45

GAT GCC CCA GCT GGT ACA AAC ATT ACG TGC ACG GGA AAT GCC TGC CCC 192  
 Asp Ala Pro Ala Gly Thr Asn Ile Thr Cys Thr Gly Asn Ala Cys Pro  
 50 55 60

GAG GTA GAG AAG GCG GAT GCA ACG TTT CTC TAC TCG TTT GAA GAC TCT 240  
 Glu Val Glu Lys Ala Asp Ala Thr Phe Leu Tyr Ser Phe Glu Asp Ser  
 65 70 75 80

GGA GTG GGC GAT GTC ACC GGC TTC CTT GCT CTC GAC AAC ACG AAC AAA 288  
 Gly Val Gly Asp Val Thr Gly Phe Leu Ala Leu Asp Asn Thr Asn Lys  
 85 90 95

TTG ATC GTC CTC TCT TTC CGT GGC TCT CGT TCC ATA GAG AAC TGG ATC 336  
 Leu Ile Val Leu Ser Phe Arg Gly Ser Arg Ser Ile Glu Asn Trp Ile  
 100 105 110

GGG AAT CTT AAC TTC GAC TTG AAA GAA ATA AAT GAC ATT TGC TCC GGC 384  
 Gly Asn Leu Asn Phe Asp Leu Lys Glu Ile Asn Asp Ile Cys Ser Gly  
 115 120 125

|    |   |     |
|----|---|-----|
|    | TGC AGG GGA CAT GAC GGC TTC ACT TCG TCC TGG AGG TCT GTA GCC GAT<br>Cys Arg Gly His Asp Gly Phe Thr Ser Ser Trp Arg Ser Val Ala Asp<br>130 135 140     | 432 |
| 5  | ACG TTA AGG CAG AAG GTG GAG GAT GCT GTG AGG GAG CAT CCC GAC TAT<br>Thr Leu Arg Gln Lys Val Glu Asp Ala Val Arg Glu His Pro Asp Tyr<br>145 150 155 160 | 480 |
| 10 | CGC GTG GTG TTT ACC GGA CAT AGC TTG GGT GGT GCA TTG GCA ACT GTT<br>Arg Val Val Phe Thr Gly His Ser Leu Gly Gly Ala Leu Ala Thr Val<br>165 170 175     | 528 |
| 15 | GCC GGA GCA GAC CTG CGT GGA AAT GGG TAT GAT ATC GAC GTG TTT TCA<br>Ala Gly Ala Asp Leu Arg Gly Asn Gly Tyr Asp Ile Asp Val Phe Ser<br>180 185 190     | 576 |
| 20 | TAT GGC GCC CCC CGA GTC GGA AAC AGG GCT TTT GCA GAA TTC CTG ACC<br>Tyr Gly Ala Pro Arg Val Gly Asn Arg Ala Phe Ala Glu Phe Leu Thr<br>195 200 205     | 624 |
| 25 | GTA CAG ACC GGC GGA ACA CTC TAC CGC ATT ACC CAC ACC AAT GAT ATT<br>Val Gln Thr Gly Gly Thr Leu Tyr Arg Ile Thr His Thr Asn Asp Ile<br>210 215 220     | 672 |
| 30 | GTC CCT AGA CTC CCG CCG CGC GAA TTC GGT TAC AGC CAT TCT AGC CCA<br>Val Pro Arg Leu Pro Pro Arg Glu Phe Gly Tyr Ser His Ser Ser Pro<br>225 230 235 240 | 720 |
| 35 | GAG TAC TGG ATC AAA TCT GGA ACC CTT GTC CCC GTC ACC CGA AAC GAT<br>Glu Tyr Trp Ile Lys Ser Gly Thr Leu Val Pro Val Thr Arg Asn Asp<br>245 250 255     | 768 |
| 40 | ATC GTG AAG ATA GAA GGC ATC GAT GGC ACC GGC GGC AAT AAC CAG CCT<br>Ile Val Lys Ile Glu Gly Ile Asp Ala Thr Gly Gly Asn Asn Gln Pro<br>260 265 270     | 816 |
| 45 | AAC ATT CCG GAT ATC CCT GCG CAC CTA TGG TAC TTC GGG TTA ATT GGG<br>Asn Ile Pro Asp Ile Pro Ala His Leu Trp Tyr Phe Gly Leu Ile Gly<br>275 280 285     | 864 |
| 50 | ACA TGT CTT TAG<br>Thr Cys Leu *  | 876 |
| 55 | 290   |     |

## (2) INFORMATION FOR SEQ ID NO: 11:

- (i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 292 amino acids  
 (B) TYPE: amino acid  
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 11:

|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |  |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|--|
| Met | Arg | Ser | Ser | Leu | Val | Leu | Phe | Phe | Val | Ser | Ala | Trp | Thr | Ala | Leu |  |
| 1   |     |     |     | 5   |     |     |     |     | 10  |     |     |     |     | 15  |     |  |
| Ala | Ser | Pro | Ile | Arg | Arg | Glu | Val | Ser | Gln | Asp | Leu | Phe | Asn | Gln | Phe |  |
|     |     |     | 20  |     |     |     |     | 25  |     |     |     |     | 30  |     |     |  |
| Asn | Leu | Phe | Ala | Gln | Tyr | Ser | Ala | Ala | Ala | Tyr | Cys | Gly | Lys | Asn | Asn |  |
|     |     |     | 35  |     |     |     | 40  |     |     |     |     | 45  |     |     |     |  |
| Asp | Ala | Pro | Ala | Gly | Thr | Asn | Ile | Thr | Cys | Thr | Gly | Asn | Ala | Cys | Pro |  |
|     | 50  |     |     |     |     | 55  |     |     |     |     | 60  |     |     |     |     |  |

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Glu Val Glu Lys Ala Asp Ala Thr Phe Leu Tyr Ser Phe Glu Asp Ser  
 65 70 75 80  
 5 Gly Val Gly Asp Val Thr Gly Phe Leu Ala Leu Asp Asn Thr Asn Lys  
 85 90 95  
 Leu Ile Val Leu Ser Phe Arg Gly Ser Arg Ser Ile Glu Asn Trp Ile  
 100 105 110  
 10 Gly Asn Leu Asn Phe Asp Leu Lys Glu Ile Asn Asp Ile Cys Ser Gly  
 115 120 125  
 Cys Arg Gly His Asp Gly Phe Thr Ser Ser Trp Arg Ser Val Ala Asp  
 130 135 140  
 15 Thr Leu Arg Gln Lys Val Glu Asp Ala Val Arg Glu His Pro Asp Tyr  
 145 150 155 160  
 20 Arg Val Val Phe Thr Gly His Ser Leu Gly Gly Ala Leu Ala Thr Val  
 165 170 175  
 Ala Gly Ala Asp Leu Arg Gly Asn Gly Tyr Asp Ile Asp Val Phe Ser  
 180 185 190  
 25 Tyr Gly Ala Pro Arg Val Gly Asn Arg Ala Phe Ala Glu Phe Leu Thr  
 195 200 205  
 Val Gln Thr Gly Gly Thr Leu Tyr Arg Ile Thr His Thr Asn Asp Ile  
 210 215 220  
 30 Val Pro Arg Leu Pro Pro Arg Glu Phe Gly Tyr Ser His Ser Ser Pro  
 225 230 235 240  
 35 Glu Tyr Trp Ile Lys Ser Gly Thr Leu Val Pro Val Thr Arg Asn Asp  
 245 250 255  
 Ile Val Lys Ile Glu Gly Ile Asp Ala Thr Gly Gly Asn Asn Gln Pro  
 260 265 270  
 40 Asn Ile Pro Asp Ile Pro Ala His Leu Trp Tyr Phe Gly Leu Ile Gly  
 275 280 285  
 Thr Cys Leu \*  
 290

45

## (2) INFORMATION FOR SEQ ID NO: 12:

- 50 (i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 876 base pairs  
 (B) TYPE: nucleic acid  
 (C) STRANDEDNESS: single  
 (D) TOPOLOGY: circular  
 55 (ii) MOLECULE TYPE: other nucleic acid  
 (A) DESCRIPTION: /desc = "Vector pJS037"  
 (vi) ORIGINAL SOURCE:  
 (B) STRAIN: *Humicola lanuginosa*  
 60 (ix) FEATURE:  
 (A) NAME/KEY: CDS  
 (B) LOCATION: 1..876  
 65 (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 12:

|    |   |     |
|----|---|-----|
|    | ATG AGG AGC TCC CTT GTG CTG TTC TTT GTC TCT GCG TGG ACG GCC TTG | 48  |
|    | Met Arg Ser Ser Leu Val Leu Phe Phe Val Ser Ala Trp Thr Ala Leu |     |
|    | 1 5 10 15   |     |
| 5  | GCC AGT CCT ATA CGT AGA GAG GTC TCG CAG GAT CTG TTT AAC CAG TTC | 96  |
|    | Ala Ser Pro Ile Arg Arg Glu Val Ser Gln Asp Leu Phe Asn Gln Phe |     |
|    | 20 25 30  |     |
| 10 | AAT CTC TTT GCA CAG TAT TCA GCT GCC GCA TAC TGC GGA AAA AAC AAT | 144 |
|    | Asn Leu Phe Ala Gln Tyr Ser Ala Ala Ala Tyr Cys Gly Lys Asn Asn |     |
|    | 35 40 45  |     |
| 15 | GAT GCC CCA GCA GGT ACA AAC ATT ACG TGC ACG GGA AAT GCA TGC CCC | 192 |
|    | Asp Ala Pro Ala Gly Thr Asn Ile Thr Cys Thr Gly Asn Ala Cys Pro |     |
|    | 50 55 60  |     |
| 20 | GAG GTA GAG AAG GCG GAT GCA ACG TTT CTC TAC TCG TTT GAA GAC TCT | 240 |
|    | Glu Val Glu Lys Ala Asp Ala Thr Phe Leu Tyr Ser Phe Glu Asp Ser |     |
|    | 65 70 75 80   |     |
| 25 | GGA GTG GGC GAT GTC ACC GGC TTC CTT GCT CTC GAC AAC ACG AAC AAG | 288 |
|    | Gly Val Gly Asp Val Thr Gly Phe Leu Ala Leu Asp Asn Thr Asn Lys |     |
|    | 85 90 95  |     |
| 30 | CTT ATC GTC CTC TCT TTC CGT GGC TCA AGA TCT ATA GAG AAC TGG ATC | 336 |
|    | Leu Ile Val Leu Ser Phe Arg Gly Ser Arg Ser Ile Glu Asn Trp Ile |     |
|    | 100 105 110   |     |
| 35 | GGG AAT CTT AAC TTC GAC TTG AAA GAA ATA AAT GAC ATT TGC TCC GGC | 384 |
|    | Gly Asn Leu Asn Phe Asp Leu Lys Glu Ile Asn Asp Ile Cys Ser Gly |     |
|    | 115 120 125   |     |
| 40 | TGC AGG GGA CAT GAC GGC TTC ACT TCG TCC TGG AGG TCT GTA GCC GAT | 432 |
|    | Cys Arg Gly His Asp Gly Phe Thr Ser Ser Trp Arg Ser Val Ala Asp |     |
|    | 130 135 140   |     |
| 45 | ACG TTA AGG CAG AAG GTG GAG GAT GCT GTT CGC GAG CAT CCC GAC TAT | 480 |
|    | Thr Leu Arg Gln Lys Val Glu Asp Ala Val Arg Glu His Pro Asp Tyr |     |
|    | 145 150 155 160   |     |
| 50 | CGC GTG GTG TTT ACC GGC CAT AGC CTT GGT GGT GCG CTA GCA ACT GTT | 528 |
|    | Arg Val Val Phe Thr Gly His Ser Leu Gly Gly Ala Leu Ala Thr Val |     |
|    | 165 170 175   |     |
| 55 | GCC GGA GCA GAC CTG CGT GGA AAT GGG TAT GAT ATC GAC GTG TTT TCA | 576 |
|    | Ala Gly Ala Asp Leu Arg Gly Asn Gly Tyr Asp Ile Asp Val Phe Ser |     |
|    | 180 185 190   |     |
| 60 | TAT GGC GCC CCC CGA GTC GGT AAC CGT GCT TTT GCA GAA TTC CTG ACC | 624 |
|    | Tyr Gly Ala Pro Arg Val Gly Asn Arg Ala Phe Ala Glu Phe Leu Thr |     |
|    | 195 200 205   |     |
| 65 | GTA CAG ACC GGC GGT ACC CTC TAC CGC ATT ACC CAC ACC AAT GAT ATT | 672 |
|    | Val Gln Thr Gly Gly Thr Leu Tyr Arg Ile Thr His Thr Asn Asp Ile |     |
|    | 210 215 220   |     |
| 70 | GTC CCT AGA CTC CCG CCT CGA GAA TTC GGT TAC AGC CAT TCT AGC CCA | 720 |
|    | Val Pro Arg Leu Pro Pro Arg Glu Phe Gly Tyr Ser His Ser Ser Pro |     |
|    | 225 230 235 240   |     |
| 75 | GAG TAC TGG ATC AAA TCT GGA ACA CTA GTC CCC GTC ACC CGA AAC GAT | 768 |
|    | Glu Tyr Trp Ile Lys Ser Gly Thr Leu Val Pro Val Thr Arg Asn Asp |     |
|    | 245 250 255   |     |
| 80 | ATC GTG AAG ATA GAA GGC ATC GAT GCC ACC GGC GGC AAT AAC CAG CCT | 816 |
|    | Ile Val Lys Ile Glu Gly Ile Asp Ala Thr Gly Gly Asn Asn Gln Pro |     |
|    | 260 265 270   |     |



5 AAC ATT CCG GAT ATC CCT GCG CAC CTA TGG TAC TTC GGG TTA ATT GGG 864  
 Asn Ile Pro Asp Ile Pro Ala His Leu Trp Tyr Phe Gly Leu Ile Gly  
 275 280 285

ACA TGT CTT TAG 876  
 Thr Cys Leu \*  
 290

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(2) INFORMATION FOR SEQ ID NO: 13:

15 (i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 292 amino acids  
 (B) TYPE: amino acid  
 (D) TOPOLOGY: linear

20 (ii) MOLECULE TYPE: protein  
 (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 13:

Met Arg Ser Ser Leu Val Leu Phe Phe Val Ser Ala Trp Thr Ala Leu  
 1 5 10 15  
 25 Ala Ser Pro Ile Arg Arg Glu Val Ser Gln Asp Leu Phe Asn Gln Phe  
 20 25 30  
 Asn Leu Phe Ala Gln Tyr Ser Ala Ala Ala Tyr Cys Gly Lys Asn Asn  
 35 35 40 45  
 30 Asp Ala Pro Ala Gly Thr Asn Ile Thr Cys Thr Gly Asn Ala Cys Pro  
 50 55 60  
 Glu Val Glu Lys Ala Asp Ala Thr Phe Leu Tyr Ser Phe Glu Asp Ser  
 35 65 70 75 90  
 Gly Val Gly Asp Val Thr Gly Phe Leu Ala Leu Asp Asn Thr Asn Lys  
 85 90 95  
 40 Leu Ile Val Leu Ser Phe Arg Gly Ser Arg Ser Ile Glu Asn Trp Ile  
 100 105 110  
 Gly Asn Leu Asn Phe Asp Leu Lys Glu Ile Asn Asp Ile Cys Ser Gly  
 115 120 125  
 45 Cys Arg Gly His Asp Gly Phe Thr Ser Ser Trp Arg Ser Val Ala Asp  
 130 135 140  
 Thr Leu Arg Gln Lys Val Glu Asp Ala Val Arg Glu His Pro Asp Tyr  
 145 150 155 160  
 50 Arg Val Val Phe Thr Gly His Ser Leu Gly Gly Ala Leu Ala Thr Val  
 165 170 175  
 55 Ala Gly Ala Asp Leu Arg Gly Asn Gly Tyr Asp Ile Asp Val Phe Ser  
 180 185 190  
 Tyr Gly Ala Pro Arg Val Gly Asn Arg Ala Phe Ala Glu Phe Leu Thr  
 195 200 205  
 60 Val Gln Thr Gly Gly Thr Leu Tyr Arg Ile Thr His Thr Asn Asp Ile  
 210 215 220  
 Val Pro Arg Leu Pro Pro Arg Glu Phe Gly Tyr Ser His Ser Ser Pro  
 225 230 235 240  
 65 Glu Tyr Trp Ile Lys Ser Gly Thr Leu Val Pro Val Thr Arg Asn Asp  
 245 250 255

Ile Val Lys Ile Glu Gly Ile Asp Ala Thr Gly Gly Asn Asn Gln Pro  
 260 265 270

5 Asn Ile Pro Asp Ile Pro Ala His Leu Trp Tyr Phe Gly Leu Ile Gly  
 275 280 285

Thr Cys Leu \*  
 290

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(2) INFORMATION FOR SEQ ID NO: 14:

15 (i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 864 base pairs  
 (B) TYPE: nucleic acid  
 (C) STRANDEDNESS: single  
 (D) TOPOLOGY: linear

20 (ii) MOLECULE TYPE: DNA (genomic)

(vi) ORIGINAL SOURCE:  
 (B) STRAIN: Pseudomonas sp.

25 (ix) FEATURE:  
 (A) NAME/KEY: mat\_peptide  
 (B) LOCATION:1..864

30 (ix) FEATURE:  
 (A) NAME/KEY: CDS  
 (B) LOCATION:1..864

35 (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 14:

|    |   |     |
|----|---|-----|
| 35 | TTC GGC TCC TCG AAC TAC ACC AAG ACC CAG TAC CCG ATC GTC CTG ACC | 48  |
|    | Phe Gly Ser Ser Asn Tyr Thr Lys Thr Gln Tyr Pro Ile Val Leu Thr |     |
|    | 1 5 10 15   |     |
| 40 | CAC GGC ATG CTC GGT TTC GAC AGC CTG CTT GGA GTC GAC TAC TGG TAC | 96  |
|    | His Gly Met Leu Gly Phe Asp Ser Leu Leu Gly Val Asp Tyr Trp Tyr |     |
|    | 20 25 30  |     |
| 45 | GGC ATT CCC TCA GCC CTG CGT AAA GAC GGC GCC ACC GTC TAC GTC ACC | 144 |
|    | Gly Ile Pro Ser Ala Leu Arg Lys Asp Gly Ala Thr Val Tyr Val Thr |     |
|    | 35 40 45  |     |
| 50 | GAA GTC AGC CAG CTC GAC ACC TCC GAA GCC CGA GGT GAG CAA CTG CTG | 192 |
|    | Glu Val Ser Gln Leu Asp Thr Ser Glu Ala Arg Gly Glu Gln Leu Leu |     |
|    | 50 55 60  |     |
| 55 | ACC CAA GTC GAG GAA ATC GTG GCC ATC AGC GGC AAG CCC AAG GTC AAC | 240 |
|    | Thr Gln Val Glu Glu Ile Val Ala Ile Ser Gly Lys Pro Lys Val Asn |     |
|    | 65 70 75 80   |     |
| 60 | CTG TTC GGC CAC AGC CAT GGC GGG CCT ACC ATC CGC TAC GTT GCC GCC | 288 |
|    | Leu Phe Gly His Ser His Gly Gly Pro Thr Ile Arg Tyr Val Ala Ala |     |
|    | 85 90 95  |     |
| 65 | GTG CGC CCG GAT CTG GTC GCC TCG GTC ACC AGC ATT GGC GCG CCG CAC | 336 |
|    | Val Arg Pro Asp Leu Val Ala Ser Val Thr Ser Ile Gly Ala Pro His |     |
|    | 100 105 110   |     |
| 65 | AAG GGT TCG GCC ACC GCC GAC TTC ATC CGC CAG GTG CCG GAA GGA TCG | 384 |
|    | Lys Gly Ser Ala Thr Ala Asp Phe Ile Arg Gln Val Pro Glu Gly Ser |     |
|    | 115 120 125   |     |

|    |   |     |
|----|---|-----|
|    | GCC AGC GAA GCG ATT CTG GCC GGG ATC GTC AAT GGT CTG GGT GCG CTG<br>Ala Ser Glu Ala Ile Leu Ala Gly Ile Val Asn Gly Leu Gly Ala Leu<br>130 135 140     | 432 |
| 5  | ATC AAC TTC CTT TCC GGC AGC AGT TCG GAC ACC CCA CAG AAC TCG CTG<br>Ile Asn Phe Leu Ser Gly Ser Ser Ser Asp Thr Pro Gln Asn Ser Leu<br>145 150 155 160 | 480 |
| 10 | GGC ACG CTG GAG TCA CTG AAC TCC GAA GGC GCC GCA CGG TTT AAC GCC<br>Gly Thr Leu Glu Ser Leu Asn Ser Glu Gly Ala Ala Arg Phe Asn Ala<br>165 170 175     | 528 |
| 15 | CGC TTC CCC CAG GGG GTA CCA ACC AGC GCC TGC GGC GAG GGC GAT TAC<br>Arg Phe Pro Gln Gly Val Pro Thr Ser Ala Cys Gly Glu Gly Asp Tyr<br>180 185 190     | 576 |
| 20 | GTG GTC AAT GGC GTG CGC TAT TAC TCC TGG AGG GGC ACC AGC CCG CTG<br>Val Val Asn Gly Val Arg Tyr Tyr Ser Trp Arg Gly Thr Ser Pro Leu<br>195 200 205     | 624 |
| 25 | ACC AAC GTA CTC GAC CCC TCC GAC CTG CTG CTC GGC GCC ACC TCC CTG<br>Thr Asn Val Leu Asp Pro Ser Asp Leu Leu Leu Gly Ala Thr Ser Leu<br>210 215 220     | 672 |
| 30 | ACC TTC GGT TTC GAG GCC AAC GAT GGT CTG GTC GGA CGC TGC AGC TCC<br>Thr Phe Gly Phe Glu Ala Asn Asp Gly Leu Val Gly Arg Cys Ser Ser<br>225 230 235 240 | 720 |
| 35 | CGG CTG GGT ATG GTG ATC CGC GAC AAC TAC CGG ATG AAC CAC CTG GAC<br>Arg Leu Gly Met Val Ile Arg Asp Asn Tyr Arg Met Asn His Leu Asp<br>245 250 255     | 768 |
| 40 | GAG GTG AAC CAG ACC TTC GGG CTG ACC AGC ATC TTC GAG ACC AGC CCG<br>Glu Val Asn Gln Thr Phe Gly Leu Thr Ser Ile Phe Glu Thr Ser Pro<br>260 265 270     | 816 |
| 45 | GTA TCG GTC TAT CGC CAG CAA GCC AAT CGC CTG AAG AAC GCC GGG CTC<br>Val Ser Val Tyr Arg Gln Gln Ala Asn Arg Leu Lys Asn Ala Gly Leu<br>275 280 285     | 864 |

## (2) INFORMATION FOR SEQ ID NO: 15:

|    |  |
|----|--|
| 45 | (i) SEQUENCE CHARACTERISTICS:<br>(A) LENGTH: 288 amino acids<br>(B) TYPE: amino acid<br>(D) TOPOLOGY: linear<br>(ii) MOLECULE TYPE: protein<br>(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 15: |
| 50 | Phe Gly Ser Ser Asn Tyr Thr Lys Thr Gln Tyr Pro Ile Val Leu Thr<br>1 5 10 15   |
| 55 | His Gly Met Leu Gly Phe Asp Ser Leu Leu Gly Val Asp Tyr Trp Tyr<br>20 25 30  |
|    | Gly Ile Pro Ser Ala Leu Arg Lys Asp Gly Ala Thr Val Tyr Val Thr<br>35 40 45  |
| 60 | Glu Val Ser Gln Leu Asp Thr Ser Glu Ala Arg Gly Glu Gln Leu Leu<br>50 55 60  |
| 65 | Thr Gln Val Glu Glu Ile Val Ala Ile Ser Gly Lys Pro Lys Val Asn<br>65 70 75 80   |
|    | Leu Phe Gly His Ser His Gly Gly Pro Thr Ile Arg Tyr Val Ala Ala<br>85 90 95  |

Val Arg Pro Asp Leu Val Ala Ser Val Thr Ser Ile Gly Ala Pro His  
 100 105 110  
 5 Lys Gly Ser Ala Thr Ala Asp Phe Ile Arg Gln Val Pro Glu Gly Ser  
 115 120 125  
 Ala Ser Glu Ala Ile Leu Ala Gly Ile Val Asn Gly Leu Gly Ala Leu  
 130 135 140  
 10 Ile Asn Phe Leu Ser Gly Ser Ser Ser Asp Thr Pro Gln Asn Ser Leu  
 145 150 155 160  
 15 Gly Thr Leu Glu Ser Leu Asn Ser Glu Gly Ala Ala Arg Phe Asn Ala  
 165 170 175  
 Arg Phe Pro Gln Gly Val Pro Thr Ser Ala Cys Gly Glu Gly Asp Tyr  
 180 185 190  
 20 Val Val Asn Gly Val Arg Tyr Tyr Ser Trp Arg Gly Thr Ser Pro Leu  
 195 200 205  
 Thr Asn Val Leu Asp Pro Ser Asp Leu Leu Leu Gly Ala Thr Ser Leu  
 210 215 220  
 25 Thr Phe Gly Phe Glu Ala Asn Asp Gly Leu Val Gly Arg Cys Ser Ser  
 225 230 235 240  
 30 Arg Leu Gly Met Val Ile Arg Asp Asn Tyr Arg Met Asn His Leu Asp  
 245 250 255  
 Glu Val Asn Gln Thr Phe Gly Leu Thr Ser Ile Phe Glu Thr Ser Pro  
 260 265 270  
 35 Val Ser Val Tyr Arg Gln Gln Ala Asn Arg Leu Lys Asn Ala Gly Leu  
 275 280 285

## PATENT CLAIMS

1. A method for preparing polypeptide variants by shuffling different nucleotide sequences of homologous DNA sequences by *in vivo* recombination comprising the steps of
  - a) forming at least one circular plasmid comprising a DNA sequence encoding a polypeptide,
  - b) opening said circular plasmid(s) within the DNA sequence(s) encoding the polypeptide(s),
  - c) preparing at least one DNA fragment comprising a DNA sequence homologous to at least a part of the polypeptide coding region on at least one of the circular plasmid(s),
  - d) introducing at least one of said opened plasmid(s), together with at least one of said homologous DNA fragment(s) covering full-length DNA sequences encoding said polypeptide(s) or parts thereof, into a recombination host cell,
  - e) cultivating said recombination host cell, and
  - f) screening for positive polypeptide variants.
2. The method according to claim 1, wherein more than one cycle of step a) to f) are performed.
3. The method according to claims 1 and 2, wherein two or more opened plasmids are shuffled with one or more homologous DNA fragments in the same shuffling cycle.
4. The method according to any of claims 1 to 3, wherein the opened plasmid(s) is(are) gapped.
5. The method according to any of claims 1 to 4 wherein the ratio between the opened plasmid(s) and homologous DNA fragment(s) are in the range from 20:1 to 1:50, preferable from 2:1 to 1:10 (mol vector: mol fragments) with the specific concentrations being from 1 pM to 10 M of the DNA.
6. The method according to any claims 1 to 5, wherein 2 or more, preferably from 2 to 6, especially 2 to 4 of the DNA fragments have partially overlapping regions.

7. The method according to claim 6, wherein the overlapping regions of the DNA fragments lies in the range from 5 to 5000 bp, preferably from 10 bp to 500 bp, especially 10 bp to 100 bp.
- 5 8. The method according to any of claims 1 and 8, wherein at least one cycle of step a) to f) is backcrossing with the initially used DNA fragments.
- 10 9. The method according to any of claims 1 and 8, wherein the plasmid(s) is(are) opened in the region around the middle of the DNA sequence(s) encoding the polypeptide(s).
- 15 10. The method according to any of claims 1 to 9, wherein the plasmid(s) is(are) opened close to a mutation in the DNA sequence(s) encoding the polypeptide(s).
- 20 11. The method according to any of claims 1 to 10, wherein the DNA fragment(s) prepared in step c) is(are) prepared under conditions suitable for high, medium or low mutagenesis.
- 25 12. The method according to any of claims 1 to 11, wherein the polypeptides producible from the input DNA sequences are enzymes or proteins with biological activity.
- 30 13. The method according to claim 12, wherein the polypeptides are enzymes selected from the group including proteases, lipases, cutinases, cellulases, amylases, peroxidases, oxidases and phytases.
- 35 14. The method according to claim 12, wherein the polypeptides are proteins with biological activity selected from the group including insulin, ACTH, glucagon, somatostatin, somatotropin, thymosin, parathyroid hormone, pigmentary hormones, somatomedin, erythropoietin, luteinizing hormone, chorionic gonadotropin, hypothalamic releasing factors, antidiuretic hormones, thyroid stimulating hormone, relaxin, interferon, thrombopoietin (TPO) and prolactin.
- 40 15. The method according to any of claims 1 to 13, wherein at least one of the initially used input DNA sequences is a wild-type DNA sequence, such as a DNA sequence coding for wild-type enzymes, in particular lipases, derived from filamentous fungi, such as *Humicola* sp., in particular *Humicola lanuginosa*, especially *Humicola*

*lanuginosa* DSM 4109.

16. The method according to claim 15, wherein at least one of the input DNA sequences is selected from the group of vectors (a) to (f) and/or DNA fragments (g) to (aa) coding for *Humicola lanuginosa* lipase variants.
17. The method according to any of claims 1 to 13, wherein at least one of the initially used input DNA sequences is a wild-type DNA sequence, such as a DNA sequence coding for wild-type enzymes, in particular lipases, derived from filamentous fungi of the genera *Absidia*, *Rhizopus*, *Emmericella*, *Aspergillus*, *Penicillium*, *Eupenicillium*, *Paecilomyces*, *Talaromyces*, *Thermoascus* and *Sclerocleista*.
18. The method according to any of claims 1 and 13, wherein at least one of the initially used input DNA sequences is a wild-type DNA sequence, such as a DNA sequence coding for wild-type enzymes, in particular lipases, derived from bacteria, such as *Pseudomonas* sp., in particular *Ps. fragi*, *Ps. stutzeri*, *Ps. cepacia*, *Ps. fluorescens*, *Ps. plantarii*, *Ps. gladioli*, *Ps. alcaligenes*, *Ps. pseudoalcaligenes*, *Ps. mendocina*, *Ps. auroginosa*, *Ps. glumae*, *Ps. syringae*, *Ps. wisconsinensis*, or a strain of *Bacillus* sp., in particular *B. subtilis*, *B. stearothermophilus* or *B. pumilus*, or a strain of *Streptomyces* sp., in particular *S. scabies*, or a strain of *Chromobacterium* sp. in particular *C. viscosum*.
19. The method according to any of claims 1 to 13, wherein at least one of the initially used input DNA sequences is a variant DNA sequence, such as a DNA sequence coding for a variant enzyme, in particular lipase variants, derived from yeasts, such as *Candida* sp., in particular *Candida rugosa*, or *Geotrichum* sp., in particular *Geotrichum candidum*.
20. The method according to any of claims 1 to 19, wherein the homologous input DNA sequences are at least 60%, preferably at least 70%, better more than 80%, especially more than 90%, and even up to 100% homologous.
21. The method according to any of claims 1 to 20, wherein the

recombination host cell is a eukaryotic cell, such as a fungal cell or a plant cell.

22. The method according to claim 21, wherein said fungal cell is a yeast cell from the group of cell of *Saccharomyces* sp., in particular strains of *Saccharomyces cerevisiae* or *Saccharomyces kluyveri* or *Schizosaccharomyces* sp., in particular *Schizosaccharomyces pombe*, or *Kluyveromyces* sp., such as *K. lactis*, or *Hansenula* sp., in particular *H. polymorpha*, or *Pichia* sp., in particular *P. pastoris*, or a filamentous fungi from the group of *Aspergillus* sp., in particular *A. niger*, *A. nidulans* or *A. oryzae*, or *Neurospora* sp., or *Fusarium* sp., in particular *F. oxysporum*, or *Trichoderma* sp..
23. The method according to any of claims 1 to 22, wherein the plasmid DNA sequence(s) coding for the polypeptide(s) is(are) operably linked to a replication sequence.
24. The method according to claim 23, wherein the plasmid DNA sequence(s) encoding the polypeptide(s) is(are) operably linked to a functional promoter sequence.
25. The method according to claim 24, wherein the plasmid is an expression plasmid.
26. The method according to claim 25, wherein the expression plasmid is pJS026 or pJS037.
- Title: Method for preparing polypeptide variants



1/10

ATGAGGAGCTCCCTTGTGCTGTTCTTTGTCTCTGCGTGGACGGCCTTGGCCAGTCTCTATT  
5447 ----- 5506  
1 M R S S L V L F F V S A W T A L A S P I -  
CGTCGAGAGGTCTCGCAGGATCTGTTTAACCAGTTCAATCTCTTTGCACAGTATTCTGCA  
5507 ----- 5566  
21 R R E V S Q D L F N Q F N L F A Q Y S A -  
GCCGCATACTGCGGAAAAACAATGATGCCCCAGCTGGTACAAACATTACGTGCACGGGA  
5567 ----- 5626  
41 A A Y C G K N N D A P A G T N I T C T G -  
AATGCCTGCCCCGAGGTAGAGAAGGCGGATGCAACGTTTCTCTACTCGTTTGAAGACTCT  
5627 ----- 5686  
61 N A C P E V E K A D A T F L Y S F E D S -  
GGAGTGGGCGATGTCACCGGCTTCCTTGCTCTCGACAACACGAACAAATGATCGTCTCTC  
5687 ----- 5746  
81 G V G D V T G F L A L D N T N K L I V L -  
TCTTTCCGTGGCTCTCGTTCATAGAGAAGTGGATCGGGAATCTTAAGTTCGACTTGAAA  
5747 ----- 5806  
101 S F R G S R S I E N W I G N L N F D L K -  
GAAATAAATGACATTTGCTCCGGCTGCAGGGGACATGACGGCTTCACTTCGTCTGGAGG  
5807 ----- 5866  
121 E I N D I C S G C R G H D G F T S S W R -  
TCTGTAGCCGATACGTTAAGGCAGAAGGTGGAGGATGCTGTGAGGGAGCATCCCGACTAT  
5867 ----- 5926  
141 S V A D T L R Q K V E D A V R E H P D Y -  
CGCGTGGTGTTTACCGGACATAGCTTGGGTGGTGCATTGGCAACTGTTGCCGGAGCAGAC  
5927 ----- 5986  
161 R V V F T G H S L G G A L A T V A G A D -  
CTGCGTGGAATGGGTATGATATCGACGTGTTTTCATATGGCGCCCCCGAGTCGGAAAC  
5987 ----- 6046  
181 L R G N G Y D I D V F S Y G A P R V G N -  
AGGGCTTTTGCAGAATTCCTGACCGTACAGACCGGCGGAACACTCTACCGCATTACCCAC  
6047 ----- 6106  
201 R A F A E F L T V Q T G G T L Y R I T H -  
ACCAATGATATTGTCCCTAGACTCCCGCCGCGCAATTCGGTTACAGCCATTCTAGCCCA  
6107 ----- 6166  
221 T N D I V P R L P P R E F G Y S H S S P -  
GAGTACTGGATCAAATCTGGAACCCCTGTCCCCGTACCCGAAACGATATCGTGAAGATA  
6167 ----- 6226  
241 E Y W I K S G T L V P V T R N D I V K I -  
GAAGGCATCGATGCCACCGGCGCAATAACCAGCCTAACATTCCGGATATCCCTGCGCAC  
6227 ----- 6286  
261 E G I D A T G G N N Q P N I P D I P A H -  
CTATGGTACTTCGGGTTAATTGGGACATGTCTTTAG  
6287 ----- 6322  
281 L W Y F G L I G T C L \*

Fig. 1

ATGAGGAGCTCCCTTGTGCTGTTCTTTGTCTCTGCGTGGACGGCCTTGGCCAGCTCTATA

5447  
1 M R S S L V L F F V S A W T A L A S P I 5506  
SnaBI PvuII  
CGTAGAGAGGTCTCGCAGGATCTGTTTAACCAAGTTCAATCTCTTTCACAGTATTACAGCT

5507  
21 R R E V S Q D L F N Q F N L F A Q Y S A 5566

GCCGCATACTGCGGAAAAACAATGATGCCCGCAGGACAGGTTACAAACATTACGTGCACGGGA

5567  
41 A A Y C G K N N D A P A G T N I T C T G 5626  
SphI  
AATGCATGCCCCGAGGTAGAGAAGGCGGATGCAACGTTTCTCTACTCGTTTGAAGACTCT

5627  
61 N A C P E V E K A D A T F L Y S F E D S 5686  
HindIII  
GGAGTGGGCGATGTCAACGGCTTCTTGTCTCTCGACAACGAACAAGCTTATCGTCTCTC

5687  
81 G V G D V T G F L A L D N T N K L I V L 5746  
BglII  
TCTTTCCGTGGCTCAAGATCTATAGAGAACTGGATCGGGAATCTTAACTTCGACTTGAAA

5747  
101 S F R G S R S I E N W I G N L N F D L K 5806

GAAATAAATGACATTGCTCCGGCTGCAGGGGACATGACGGCTTCACTTCGTCTCGGAGG

5807  
121 E I N D I C S G C R G H D G F T S S W R 5866  
NruI  
TCTGTAGCCGATACGTTAAGGCAGAAGGTGGAGGATGCTGTTCCCGAGCATCCCGACTAT

5867  
141 S V A D T L R Q K V E D A V R E E F D Y 5926  
BstXI NheI  
CGCGTGGTGTTTACCGGCCATAGCCCTTGGTGGTGGCTAGCAACTGTTGCCGGAGCAGAC

5927  
161 R V V F T G H S L G G A L A T V A G A D 5986  
BstEII  
CTGCGTGGAAATGGGTATGATATCGACGTGTTTTTCATATGGCGCCCCCGAGTGGTAAC

5987  
181 L R G N G Y D I D V F S Y G A P R V G N 6046  
KpnI  
CGTGCTTTTGCAGAATTCTGACCGTACAGACCGGCGGTACCCCTCTACCGCATTACCCAC

6047  
201 R A F A E F L T V Q T G G T L Y R I T H 6106  
XhoI  
ACCAATGATATTGTCCCTAGACTCCCGCTCGAGAATTTCGGTTACAGCCATTCTAGCCCA

6107  
221 T N D I V P R L P P R E F G Y S H S S P 6166  
SpeI  
GAGTACTGGATCAAACTCTGGAACACTAGTCCCCGTACCCGAAACGATATCGTGAAGATA

6167  
241 E Y W I K S G T L V P V T R N D I V K I 6226

GAAGGCATCGATGCCACCGCGGCAATAACACGCTAACATTCCGGATATCCCTGCGCAC

6227  
261 E G I D A T G G N N Q P N I P D I P A H 6286

CTATGGTACTTCGGGTTAATTGGGACATGTCTTTAG

6287  
281 L W Y F G L I G T C L \* 6322

**Fig. 2**

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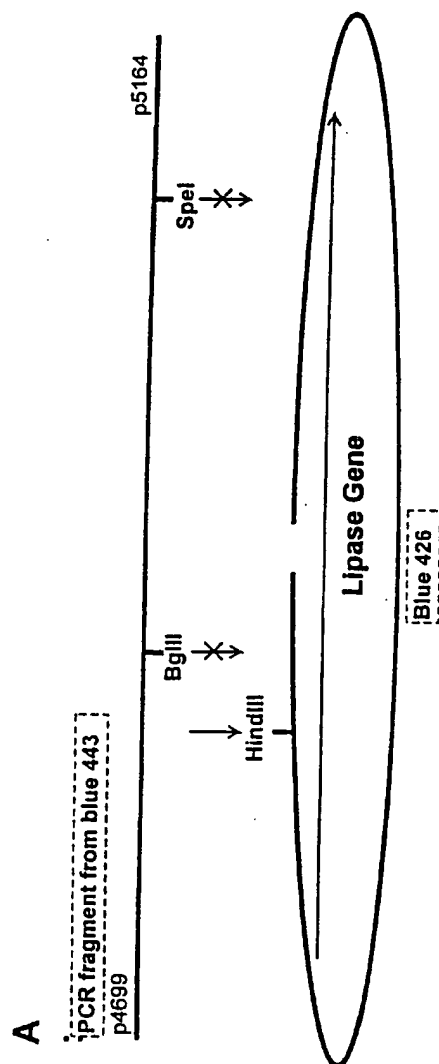


Fig. 3

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B:

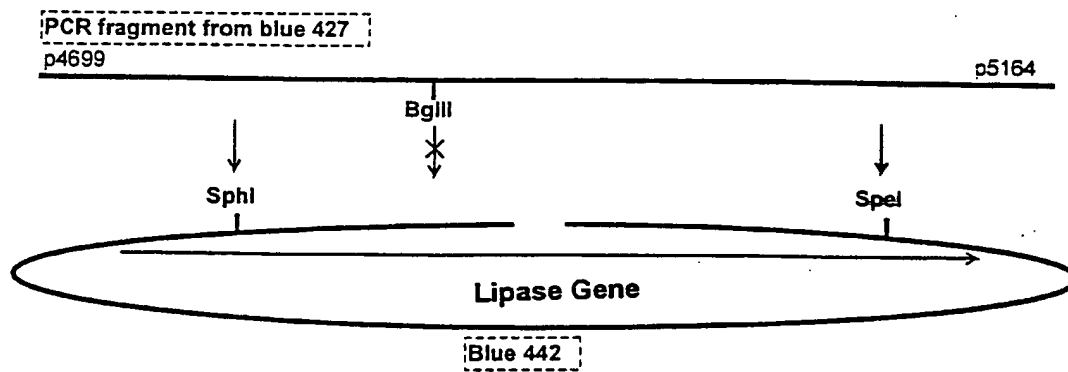


Fig. 4

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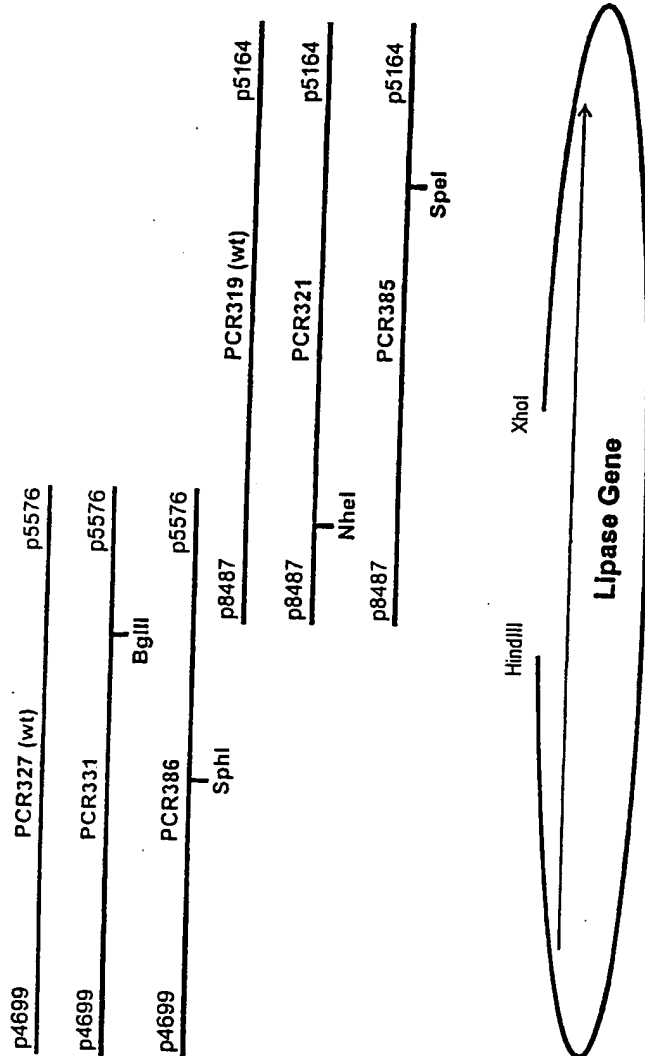


Fig. 5

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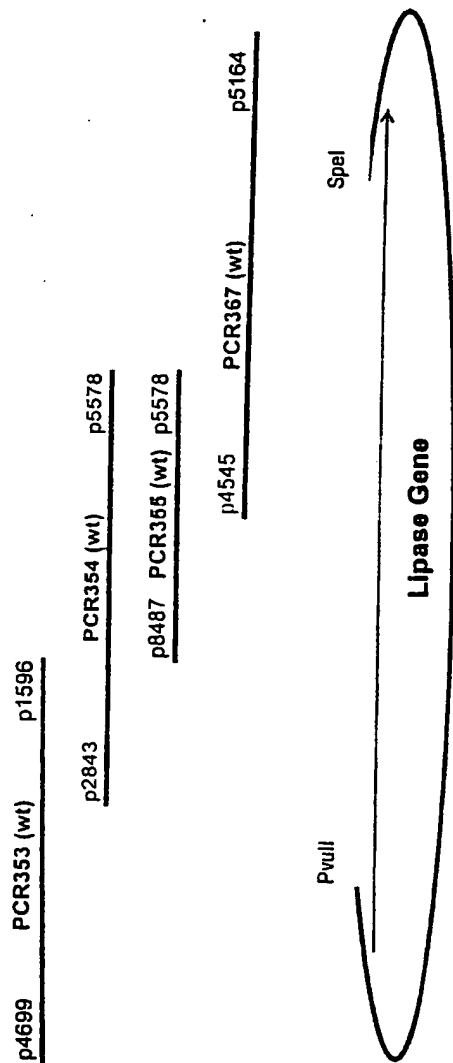


Fig. 6

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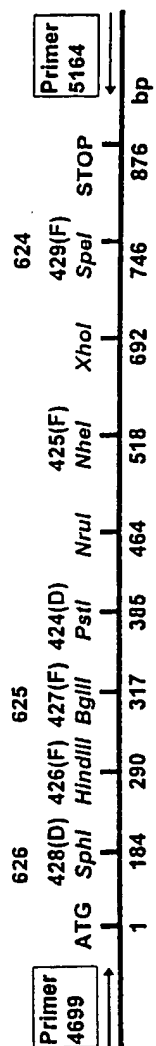


Fig. 7

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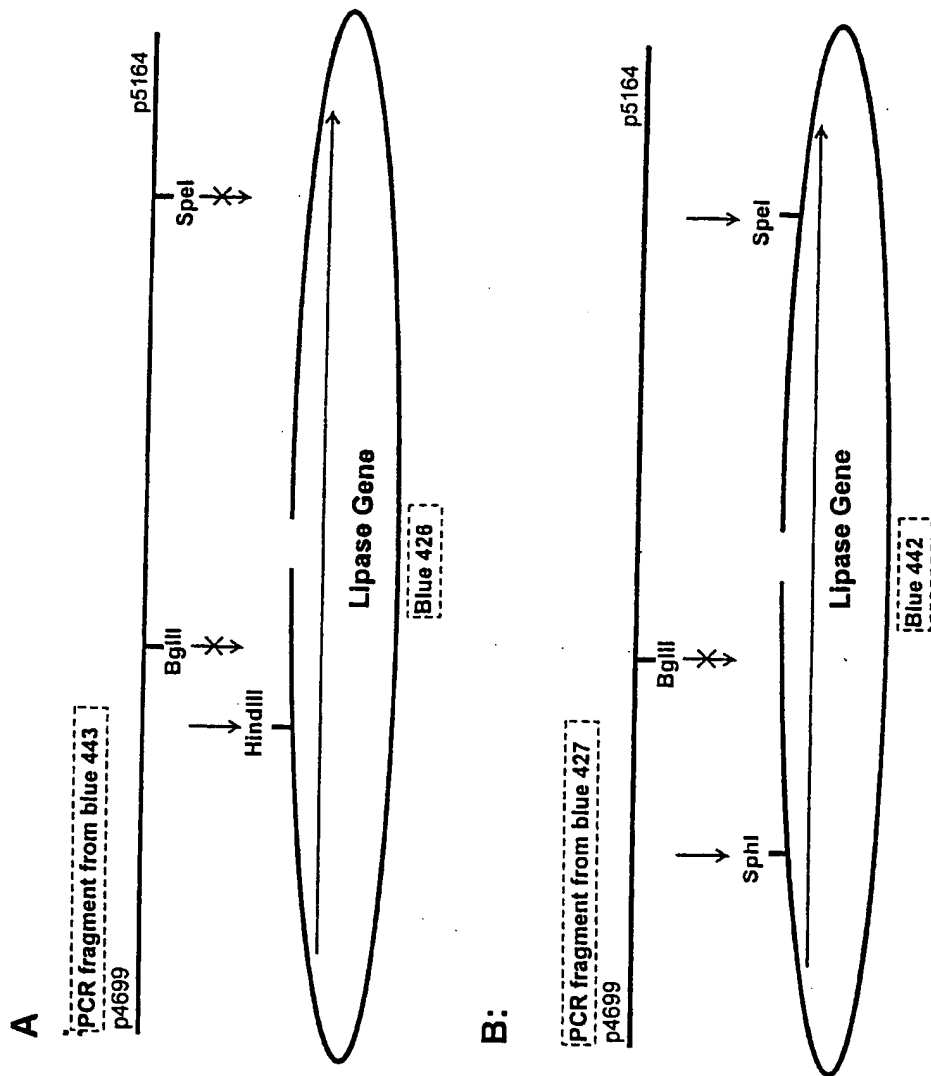


Fig. 8



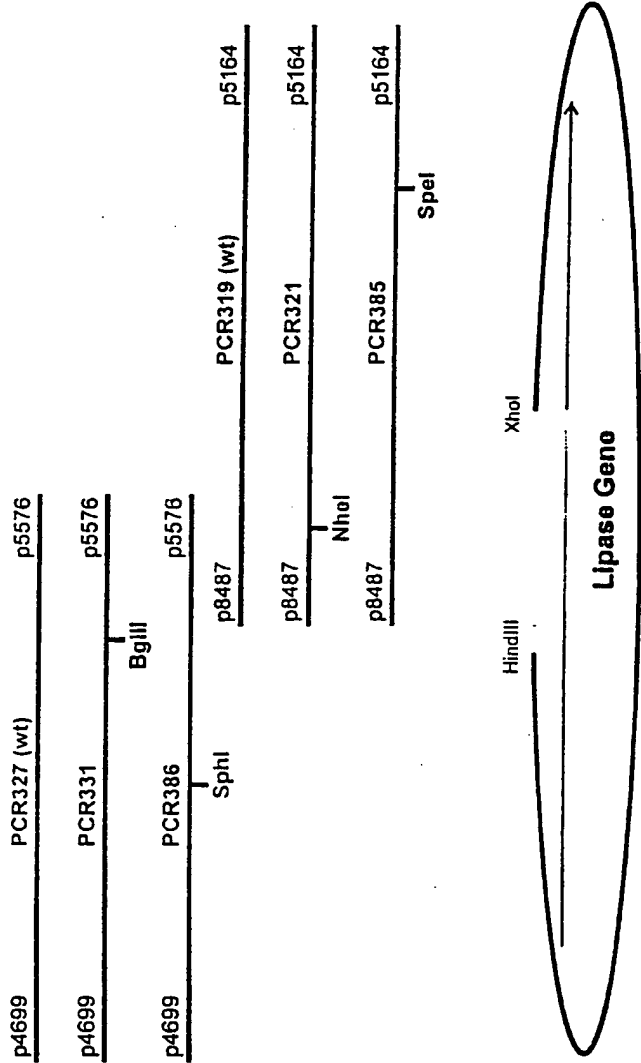


Fig. 9

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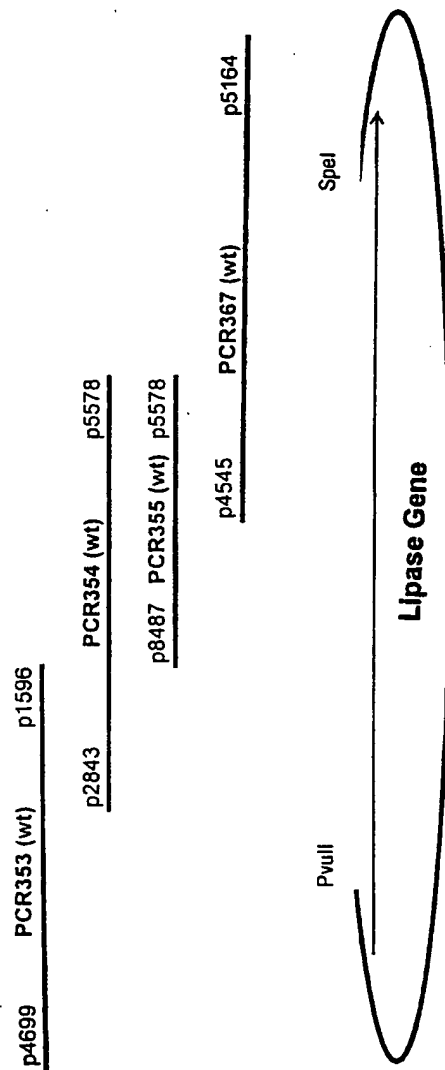


Fig. 10

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/DK 96/00343

## A. CLASSIFICATION OF SUBJECT MATTER

IPC6: C12N 15/10, C12N 15/62, C12N 15/63

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: C12N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, EPODOC, US PAT FULL, MEDLINE, BIOSIS, DBA CA, SCISEARCH, PATENT CITATION INDEX

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages   | Relevant to claim No. |
|-----------|--|-----------------------|
| X         | Gene, Volume 83, 1989, Denis Pompon et al,<br>"Protein engineering by cDNA recombination in yeasts: shuffling of mammalian cytochrome P-450 functions", page 15 - page 24, figures 1,2<br>-- | 1-26                  |
| A         | EP 0141484 A2 (BIOGEN N.V.), 15 May 1985<br>(15.05.85), figures<br>--  | 1-26                  |
| A         | US 5093257 A (GREGORY L. GRAY), 3 March 1992<br>(03.03.92), column 3, line 11 - line 13<br>--<br>-----   | 1-26                  |

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Date of the actual completion of the international search

8 November 1996

Date of mailing of the international search report

13.11.96

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

01/10/96

International application No.

PCT/DK 96/00343

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
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| US-A- 5093257                             | 03/03/92            | AU-A- 5945086              | 08/01/87            |
|   |                     | CA-A- 1312836              | 19/01/93            |
|   |                     | DE-D,T- 3688920            | 23/12/93            |
|   |                     | EP-A,B- 0208491            | 14/01/87            |
|   |                     | SE-T3- 0208491             |                     |
|   |                     | IE-B- 59875                | 20/04/94            |
|   |                     | JP-B- 8029091              | 27/03/96            |
|   |                     | JP-A- 62083891             | 17/04/87            |